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Rio Blanco Oil Shale Company

Tract C-a

Environmental Protection Agency

Prevention of Significant Deterioration Permit Application

LURGI DEMONSTRATION PROJECT

January 1981

Gulf Oil Corporation/Standard Oil Company (Indiana)
'A General Partnership'
2851 South Parker Road, Aurora, Colorado 80014

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and
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B	Fugitive Dust Calculations
C	Hydrocarbon Emission Calculations
D	Visibility Screening Test
E	Methodology for Employment and Population Projections

Sec. 1.0

1.0 INTRODUCTION

1.1 Overview

Rio Blanco Oil Shale Company (RBOSC) is proposing to construct and operate a pilot scale surface oil shale processing facility in connection with its prototype oil shale lease Tract C-a in Northwestern Colorado. In this regard RBOSC is currently applying for construction, mining and operating, special use and other permits from the USEPA, Colorado Department of Health, Colorado Mined Land Reclamation Board, Rio Blanco County, Bureau of Land Management, and other appropriate agencies. The activities to be permitted include an open pit mining operation on tract and a surface retorting facility on adjacent private land. The area which RBOSC is seeking to permit is depicted in Figure 1-1. Construction of the demonstration plant is scheduled to commence in May 1981 with startup scheduled for January 1983. This pilot scale project is termed the Lurgi Demonstration Project.

This report has been prepared to assess the air quality impact of the Lurgi Demonstration Project.

1.2 Air Quality Modeling

Since the tract is located in an air quality attainment area, RBOSC has estimated the potential impacts to air quality according to Federal requirements for Prevention of Significant Deterioriation (PSD) in compliance with Part C of the Clean Air Act.

Analyses have also been conducted to determine if ambient concentrations of pollutants in the vicinity of the project area are in compliance with National Ambient Air Quality Standards (NAAQS) and Colorado Ambient Air Quality Standards (CAAQS).

The detailed air quality assessment included in this permit application is based upon the current plans for the Lurgi Demonstration Project. Background information and a brief project description are included in Section 2.0 of this application. A more detailed discussion of the project is included in

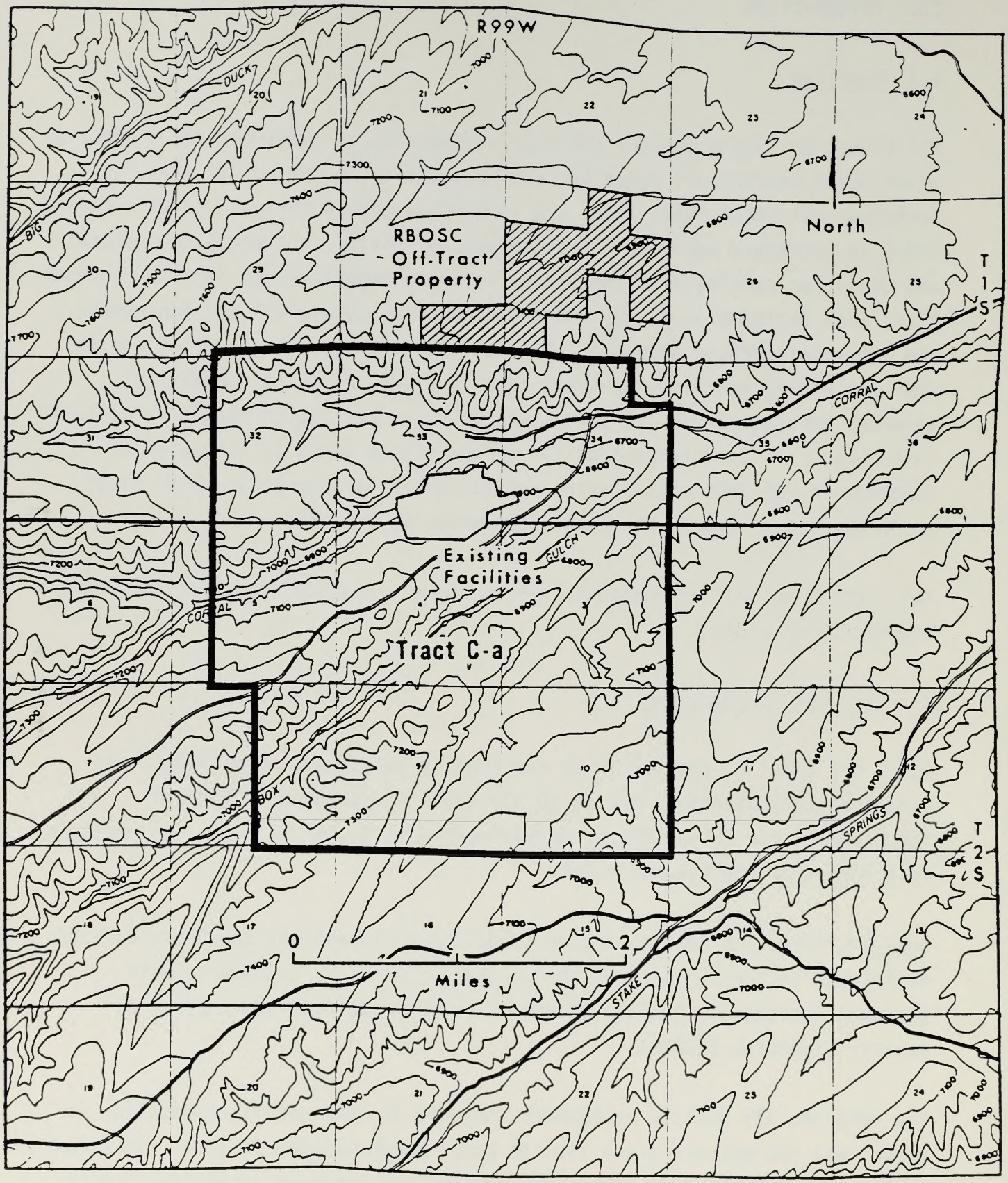


Figure 1-1
Lurgi Demonstration Project Off-Tract Site Location

the Lurgi Demonstration Project Report, a copy of which has been submitted with this permit application.

Stack and fugitive emission sources were included in the modeling analyses conducted for this application. Stack sources were assessed with ERT Gaussian plume models, including Sequential VALLEY, and the Multiple Point Source Diffusion Model (MPSDM).

Sequential VALLEY is an hour-by-hour version of the EPA VALLEY model that utilizes one year of hourly meteorological data. Sequential VALLEY was used as a screening model to provide conservative estimates of maximum concentrations in high terrain from stack emissions and to identify periods in the yearly data base conducive to worst case impact in the high terrain. MPSDM is a complex terrain model similar to Sequential VALLEY except that MPSDM has greater sophistication in the treatment of plume transport in high terrain. MPSDM was used to determine maximum Sulfur Dioxide (SO_2) and Total Suspended Particulate (TSP) impacts (from stack emissions only) in the area surrounding Tract C-a (Class II) and at the Flat Tops Wilderness Area (Class I).

The air quality impacts were evaluated for elevated emissions from Tract C-a alone and in combination with emissions from Tract C-b operations at 5,000 bbl/day, Colony operations at 46,000 bbl/day, and Union Oil operations at 10,000 bbl/day.

The MINE Model was used to estimate TSP ground level concentrations resulting from fugitive emission sources. This model was specifically designed to simulate the dispersion of point, line and area fugitive dust sources, such as those occurring from a surface mine.

Meteorological data gathered at Tract C-a were used as input to the models. These data included surface wind speed, wind direction, and temperature. Hourly values of mixing height were estimated from surface wind speed values measured at RBOSC's 60-m tower and twice daily rawinsonde observations taken in Grand Junction, Colorado. Hourly values of atmospheric stability were estimated from wind speed and temperature data measured at RBOSC's 60-m tower.

The emissions inventory, dispersion analysis and interpretation were conducted by Environmental Research and Technology, a consultant to RBOSC.

The potential emission sources associated with the Lurgi Demonstration Project include the following:

- open pit oil shale mine
- haul road and access road
- raw shale stockpile
- wind erosion from disturbed areas
- raw shale feed preparation
- Lurgi retort and ancillary process equipment
- support facilities
- processed shale disposal and wind erosion
- hydrocarbon storage tanks

Emissions of sulfur dioxide and other gases from elevated point sources were estimated based on the normal operating conditions for the 4,400 tons per day Lurgi demonstration retort. The retort flue, incinerator/scrubber, two process steam boilers, and a hot oil heater are the sources that will emit gaseous effluents under normal operating conditions. A diesel generator, diesel pumps, and flare will emit effluents on a temporary basis during startup, shutdown, or emergency operating conditions. The open pit oil shale mine, haul road and access roads, raw shale stockpile, overburden disposal, raw shale feed preparation, and processed shale disposal are the primary fugitive emission sources.

Total suspended particulates (TSP) emissions were determined by identifying all potential sources of TSP emissions and compiling a detailed emission inventory for each year of operations.

Emission factors were based on EPA Region VIII guidelines (1979), Colorado Department of Health guidelines (not dated), Wyoming Department of Environmental Quality guidelines (1979), EPA AP-42 (1977), and information obtained in various meetings with representatives of EPA Region VIII and the Colorado

Department of Health. Operational parameters and dust control techniques reflect the current mining plan.

For purposes of determining PSD increment consumption, the emissions of TSP from construction-related activities need not be considered because these activities are temporary and short-term. Construction-related emissions must be considered, however, in determining compliance with Colorado Ambient Air Quality Standards (CAAQS).

From the TSP emission inventory, it is projected that the highest emission rate for operational activities will occur in 1983. However, when emissions from construction-related activities are included with the operational sources, the highest short term emissions are projected to occur in 1981 and the highest annual emissions are anticipated in 1982. Thus modeling to determine maximum PSD increment consumption was conducted for the 1983 operational scenario. Modeling to determine compliance with Federal and State ambient air quality standards used 1981 emission estimates to determine the maximum 24-hour concentrations and 1982 emissions to estimate highest average annual concentration.

Table 1-1 summarizes the results of the PSD analysis for SO_2 and TSP. These data show that the project should not result in violations of any applicable PSD increments. Table 1-2 compares the predicted maximum ambient concentrations of criteria pollutants with Federal and State air quality standards. Based on these predictions, project-related emissions should not cause violations of ambient air quality standards.

1.3 Impacts on Visibility, Soils and Vegetation

The impacts of air pollutant emissions from the proposed Lurgi Demonstration Project on visibility, soils and vegetation were also addressed. Draft EPA guidelines for estimating visibility impairment (EPA 1980) were used to project potential visibility impacts for the Flat Tops Wilderness Area, the nearest Class I area. These calculations show that visibility impairment will not occur in this Class I area. Impacts to soils and vegetation were

TABLE 1-1

COMPARISON OF MAXIMUM PREDICTED INCREASE IN CONCENTRATIONS TO APPLICABLE PSD INCREMENTS

Pollutant	PSD Increment ($\mu g/m^3$)	Highest Model Prediction ($\mu g/m^3$)	% of Increment
Class I Areas			
Sulfur dioxide			
3-hour	25	15.6[1]	62[1]
24-hour	5	2.6[1]	52[1]
annual	2	0.4[1]	20[1]
Total Suspended Particulates			
24-hour	10	1.6[1]	16[1]
annual	5	0.3[1]	6[1]
Class II Areas			
Sulfur dioxide			
3-hour	512	83.5[1]	16[1]
24-hour	91	21.8[1]	24[1]
annual	70	2.7[1]	14[1]
Total Suspended Particulates			
24-hour	37	15.2[2]	41[2]
annual	19	3.5[2]	18[2]

[1]Due to combined emissions from Tract C-a and other regional sources.

[2]Due to Tract C-a sources alone.

TABLE 1-2

COMPARISON OF MAXIMUM PREDICTED CONCENTRATIONS TO AMBIENT AIR QUALITY STANDARDS

Pollutant	Standard ($\mu g/m^3$) Federal	State	Highest Model Prediction ($\mu g/m^3$)
Sulfur dioxide			
3-hour	1300	N/A	100
24-hour	365	N/A	38
annual	80	N/A	19
Total Suspended Particulates			
24-hour	260(150)[1]	260(150)[1]	111
annual	75(60)[1]	75(60)[1]	32
Nitrogen dioxide			
annual	100	100	22
Carbon Monoxide			
1-hour	40,000	40,000	1,130
8-hour	10,500	10,000	1,130
Photochemical Oxidant			
1-hour	235	235	--[2]

[1]Secondary standard

[2]No analysis was performed for photochemical oxidant since the project emission levels of hydrocarbons are very low.

estimated from data in the literature on the effects of air pollutants including TSP, NO_x, and SO^2 on soil and vegetation.

Based on the limited data available, no air quality related impacts should occur to trees, grasses, shrubs or forbs at Tract C-a or at the Flat Tops Wilderness Area.

1.4 Other Air Quality Considerations

RBOSC is planning to employ the best available control technology (BACT) wherever feasible to minimize particulate and gaseous emissions and to maintain air pollutants at levels below the State and Federal standards. The EPA Region VIII Interim Policy Paper on Air Quality Review of Surface Mining Operations was used as a guide for determining the applicable BACT practices.

Good Engineering Practice (GEP) for stack height and anticipated deminimis pollutant concentrations were also considered. The proposed stack heights for the Lurgi retort and incinerator scrubber will not exceed GEP guidelines for stack heights. Although existing data on the deminimis pollutants are limited, it does not appear that the project related emissions will exceed the deminimis levels specified in 40 CFR 51.24 and 52.21. RBOSC is planning additional studies in the near future to more accurately estimate the emissions of deminimis pollutants from the Lurgi retort and other project-related sources.

A series of appendices are included as part of this application to provide the following additional information:

- Detailed description of the air quality models used
- Calculations and assumptions made in developing the fugitive emission inventories and hydrocarbon emissions
- Data and calculation used to assess the visibility impacts on Flat Tops Wilderness Area
- Methods used to assess secondary emissions

Sec. 2.0

2.0 PROJECT BACKGROUND AND OVERVIEW

2.1 PROJECT BACKGROUND

2.1.1. Tract C-a - The Department of the Interior (DOI) instituted the Prototype Oil Shale Leasing Program in 1974 to encourage development of the Green River oil shale formation. Six leases were offered for sale: Two in Colorado and two in Utah were sold, but two in Wyoming received no bids from industry.

Gulf Oil Corporation and Standard Oil Company (Indiana) were awarded the lease for the first tract in the program, Colorado Tract C-a, after submitting the high bonus bid of $210,305,600. The lease was formally signed by the Colorado State Director of the Bureau of Land Management (BLM) on February 5, and became effective on March 1, 1974.

In order to effectively develop Tract C-a, Gulf and Standard organized the Rio Blanco Oil Shale Project (RBOSP) soon after obtaining the lease. In 1978 the two parent companies formed a general partnership which was renamed the Rio Blanco Oil Shale Company (RBOSC). The sole purpose of RBOSC is to develop Tract C-a.

The tract comprises about 5,100 acres or eight square miles in Rio Blanco County in western Colorado. It is about 20 miles southeast of Rangely and 200 miles west of Denver (see Figure 2-1). Total oil reserves on the tract are estimated to be nine billion barrels of which two to five billion barrels can be recovered depending on the method used.

The lease runs for 20 years after the effective date (March 1, 1974), or as long as there is commercial production from the tract, subject to readjustment of terms and conditions at 20-year intervals. Under the provisions of the lease, Gulf and Standard paid $126 million of the bonus bid in three installments, but were allowed to credit $84 million against development expenditures. A royalty will be paid on the oil produced from the tract based on the average value of oil produced in Colorado, Utah and Wyoming.

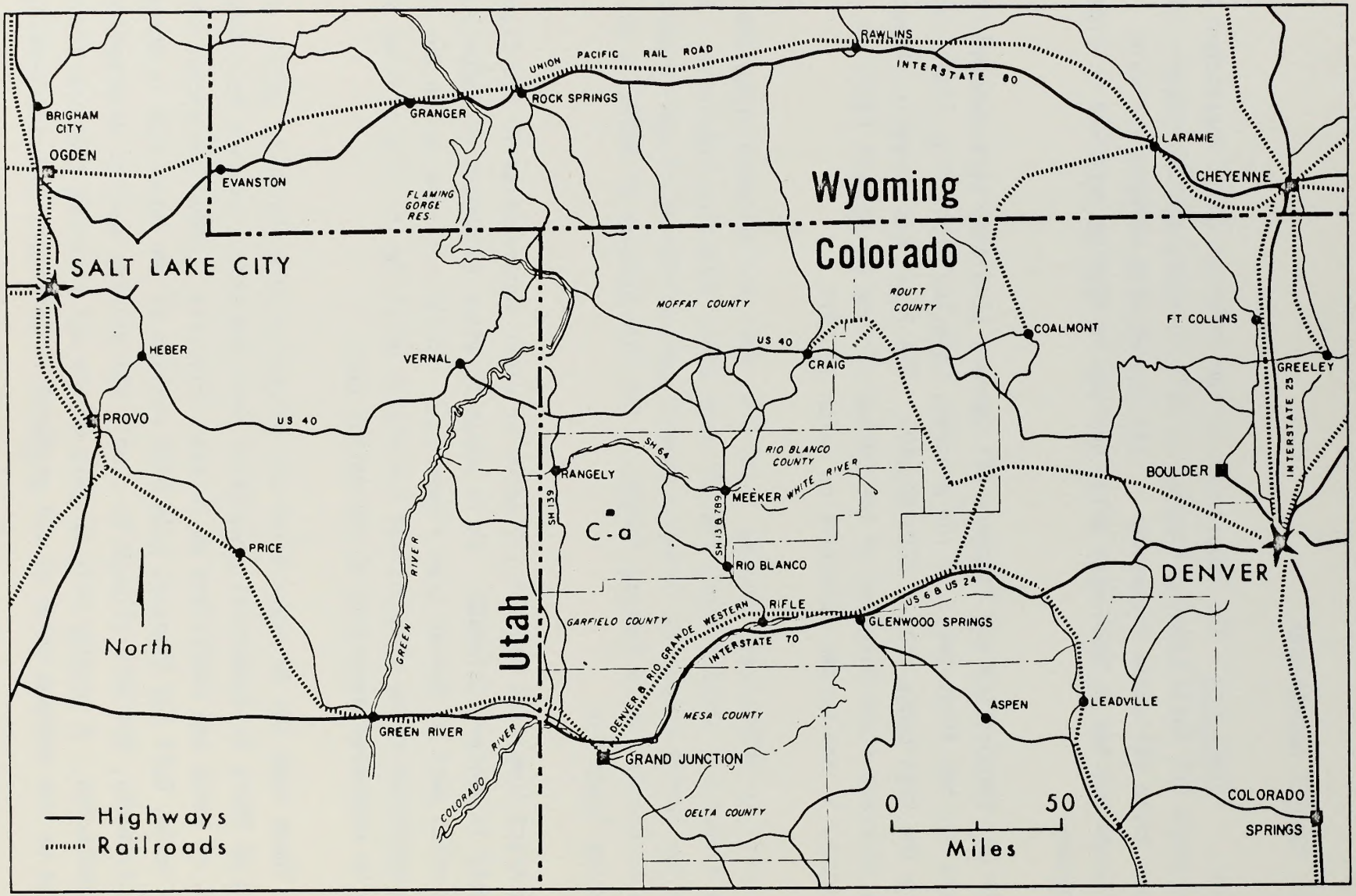


Figure 2-1

Regional Map Showing Location of Tract C-a

The lease also contains specific requirements for environmental protection and environmental monitoring.

2.1.2 Detailed Development Plan

Requirement for Detailed Development Plan - One of the requirements of the Prototype Oil Shale leases is that a Detailed Development Plan (DDP) be filed with the Area Oil Shale Supervisor (AOSS) before the third anniversary date of the lease. The purpose of the DDP is to outline a program which shows that the lessees will use due diligence for the orderly development of the tract under the terms of the lease.

DDP for Open Pit Mining - Gulf and Standard submitted a DDP to the AOSS in March 1976 which presented plans for producing oil at 50,000 barrels-per-stream-day (BPSD) from shale mined from an open pit. The oil shale would be retorted above ground. The pit was to be started in the northwest corner of the tract and would progress to the southeast. The overburden and processed shale was to be placed off-tract for the first 30 years after which pit backfilling was to begin.

The migrating open pit concept also could be applied to lands adjacent to Tract C-a. With active pit walls already exposed at the Tract C-a boundary, the pit would migrate to the south and east if additional leases were issued.

Suspension - After Gulf and Standard acquired the lease to Tract C-a, the Solicitor of the DOI ruled that the Secretary of the Interior did not have the authority to grant additional Federal leases for surface uses such as disposal and processing facility siting.

In addition, air quality monitoring showed occasional violations of Environmental Protection Agency (EPA) primary and secondary ambient air quality standards for non-methane hydrocarbons, particulates and ozone. Since this was occurring without any industry in the area, an oil shale facility could not be built.

As a result of these problems, a two-year lease suspension was requested by RBOSC. A one-year suspension was granted by the government which ran from September 1, 1976 to September 1, 1977.

Revised DDP for Modified In Situ Retorting - During the suspension, the EPA reinterpreted their position on the air quality problem so that they no longer prohibited all development. Off-tract land for disposal was still not available, however, and RBOSC reevaluated other available technologies. As a result of this examination, a Revised DDP was filed with the Area Oil Shale Office (AOSO) in May 1977, which proposed a plan for developing Tract C-a using the Modified In Situ (MIS) technique combined with surface retorting of the shale mined and brought to the surface in connection with the MIS method. The Revised DDP was approved by the AOSS in September, 1977. The plan of action for the approved DDP included surface retorting.

In the MIS process, retorts are created in the shale bed by mining some of the shale from a given volume to develop a void volume to permit retorting. The remaining shale in the volume is rubblized with explosives. Shale oil is retorted by injecting a combustion-supporting gas into the retort volume and retort products (oil, gas and water) are withdrawn to the surface. At the surface the retort products are separated, the oil is processed, the gas is purified to remove sulfur compounds and other contaminants and is used for fuel, and the water is treated and either used internally or discharged. The oil shale mined to create the in situ retorts is retorted on the surface thus producing additional oil.

A Technical Modification to the Revised DDP, which mainly concerned the method of mining underground retorts and the number of retorts scheduled to be burned during the MDP, was approved by the AOSS in August 1979.

Tract C-a Progress - MIS Retort 0 was developed and burned during the last quarter of 1980, and Retort 1 is currently being developed and will be burned during 1981.

RBOSC has been actively studying the environmental impacts which could result from development of Tract C-a. In 1977, RBOSC completed a two-year baseline

environmental program which included studies of meteorology and air quality, terrestrial and aquatic ecology, interrelationships among components of the ecosystem, and areas of cultural resources. Since completion of the baseline environmental study, the parameters of the study continued to be monitored.

2.2 LURGI DEMONSTRATION PROJECT OVERVIEW

The Revised DDP presented a 40-year plan for developing the oil shale resource on Tract C-a. The first ten years is a Modular Development Phase (MDP) in which a series of MIS retorts are developed and burned in sequence to gain operating experience, improve process efficiency, confirm capital and operating costs for a commercial operation and ensure environmental integrity of the operations.

2.2.1 Development Objectives - RBOSC is expanding the scope of the MDP to include the demonstration of a surface retort. This modification also includes a small open pit mine to provide feed shale to the surface retort. MIS development may not prove to be the best approach for the commercial development of Tract C-a. Legislation to give the Secretary of the Interior the authority to make off-tract land available failed to pass in Congress in 1980 but is expected to be reintroduced during the 1981 session of Congress. Thus, an open pit mine with a surface retort demonstration unit would be valuable to evaluate. Whether RBOSC proceeds with an MIS or open pit commercial plan, surface retorting of oil shale is required for maximum conservation of the resources.

To obtain technical, environmental and economical information on surface retorting, RBOSC entered into an agreement with Lurgi Kohle Und Mineraloltechnic GmbH for the design of a Lurgi-Ruhrgas surface oil shale retort. The Lurgi plant site and other facilities will be located on an off-tract area adjacent to Tract C-a (Figure 2-2). RBOSC agreed with the Colorado Division of Wildlife (DOW) to exchange 457 acres of State land north of and adjacent to Tract C-a for lands of equal value to be designated by the DOW. Prior to completion of the exchange, RBOSC has the full right to use the surface estate in the 457 acre parcel, including all rights for site preparation, construction and all other activities necessary for the Lurgi

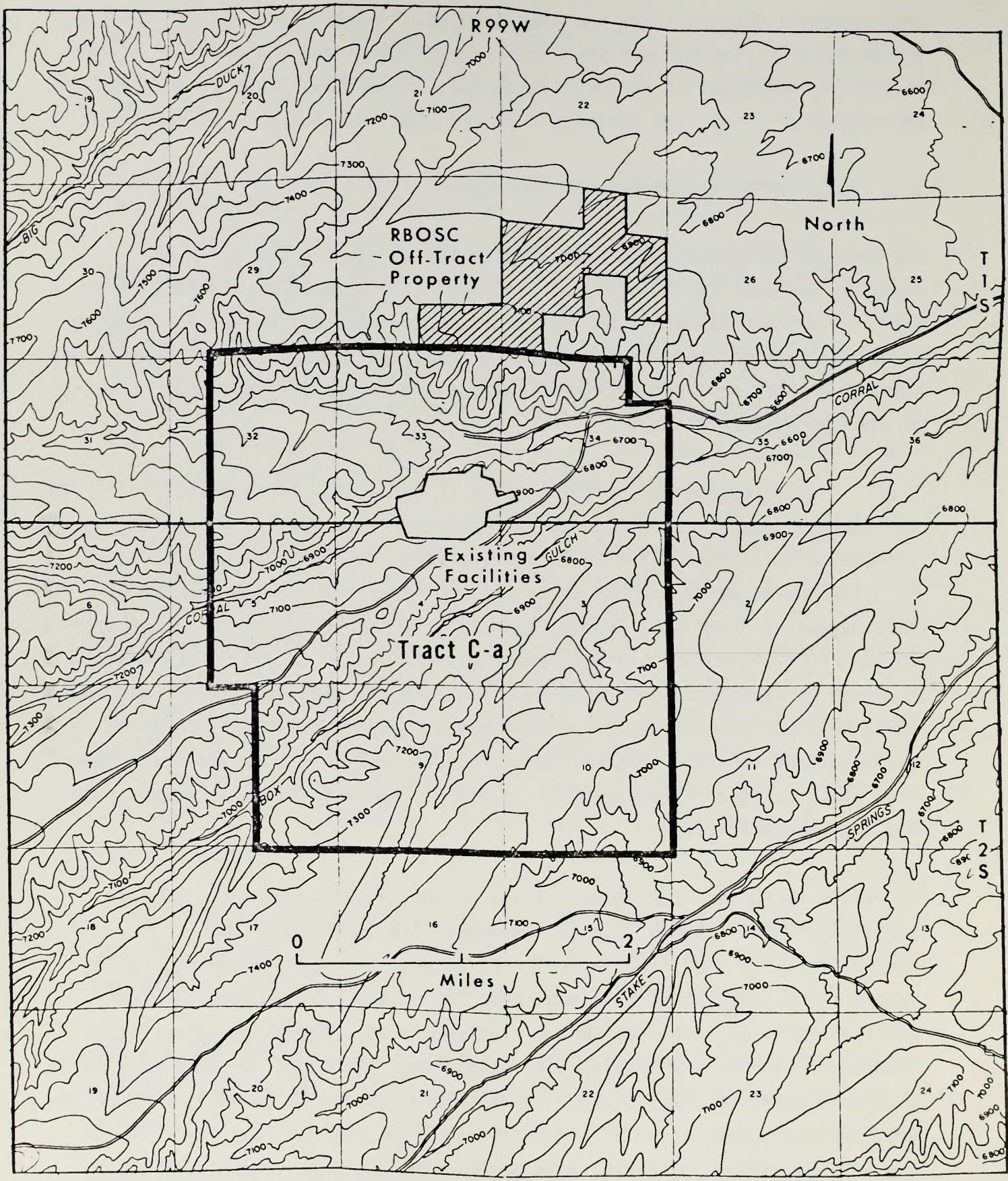


Figure 2-2

Lurgi Demonstration Project Off-Tract Site Location

Demonstration Project. Table 2-1 is a legal description of Tract C-a and the RBOSC off-tract property where the operation will occur.

The basic schedule for commercialization has not changed from the Revised DDP. If MIS retorting proves to be successful, commercial scale operations could be reached in 1987. Commercial size is generally regarded as a minimum production of 50,000 BPSD. RBOSC's plan still calls for 76,000 BPSD as shown in the Revised DDP's with 47,000 BPSD coming from MIS operations and 19,000 BPSD from surface retorting. If an open pit mining operation and surface retorting are selected for commercial operations, production of 50,000 BPSD is also possible in 1987. There would eventually be higher production, but such amounts could not be reached until the 1990's and would require expanded facilities. RBOSC will file subsequent applications for air quality permits once commercial operation plans are adequately developed.

2.2.2 Overall Project Description and Development Schedule - The proposed development plan for the Lurgi Demonstration Project described in the Technical Modification to the Revised DDP consists of a two-year construction period and up to three years of operation of a 4,400 ton per day Lurgi-Ruhrgas surface retort. The plant, support facilities and overburden and processed shale disposal sites will be located on the RBOSC off-tract property. Ore for the Lurgi retort will be obtained from a small open pit in the northwest corner of Tract C-a and the MIS run-of-mine stockpile.

This Lurgi demonstration occurs in two phases: Phase I allows technical, environmental and cost data to be gathered and evaluated to refine commercial planning and Phase II allows operations to continue and be optimized while commercial construction is underway. Table 2-2 is a summary of information pertinent to RBOSC's proposed Lurgi Demonstration Project. Figure 2-3 is a plot plan for the project development and operation. Figure 2-4 shows the Lurgi Demonstration Project Construction and Operations Schedule. The information presented above and throughout this document is based on the design to date. As detailed engineering and design proceeds, specific details may vary somewhat, but the overall concepts presented should remain the same. The following presents a summary of the Lurgi Demonstration Project. A complete

TABLE 2-1

LEGAL DESCRIPTION OF TRACT C-a AND THE RBOSC OFF-TRACT PRIVATE PROPERTY

TRACT C-A

T. 1 S., R. 99 W., 6th P.M.

Section 32: E½, E½W½
Section 33: All
Section 34: W½, SE¼, W½NE¼, SE¼NE¼

T. 2 S., R. 99 W., 6th P.M.

Section 3: All
Section 4: All
Section 5: E½, E½W½ (including Lots 1, 2 and 3)
Section 8: E½
Section 9: All
Section 10: All

situated in the County of Rio Blanco, State of Colorado containing 5,089.70 acres, more or less, identified as "Tract C-a";

RBOSC OFF-TRACT PRIVATE PROPERTY

T. 1 S., R. 99 W., 6th P.M.

Section 27: NW¼NE¼, S½NE¼, S½NW¼, N½SW¼, SW¼SW¼ and NE¼SE¼

Section 28: S½SE¼

situated in the County of Rio Blanco, State of Colorado containing 457 acres, more or less.

TABLE 2-2

LURGI DEMONSTRATION PROJECT SUMMARY

	PHASE I	PHASE II
TIMING		
Construction		
Process Plant	May 81 - Jan 83	
Mine (Overburden Stripping)	May 81 - Feb 83	Nov 83 - Feb 85
Operation		
Process Plant	Jan 83 - July 84	July 84 - Jan 86
Mine (Ore Production)	Feb 83 - Apr 83	Feb 85 - May 85
MINING		
Type	Open Pit	Open Pit
Overburden Quantity	5.2 mm/bcy	4.2 mm/bcy
Overburden Haulage	Truck	Truck
Ore Production	1.2 mm Tons	1.8 mm Tons
Ore Haulage	Truck	Truck
Transfer from MIS Stockpile	Up to 0.3 MM Tons	
MIS Ore Haulage	Truck	
PROCESSING		
Retorting	Lurgi 4400 TPD Unit	Lurgi 4400 TPD Unit
Processed Shale Quantity	1.2 mm Tons	1.8 mm Tons
Processed Shale Haulage	Conveyor Belts	Conveyor Belts
Stream Days	0.5 Factor	0.75 Factor
PRODUCT SHALE OIL		
Transportation	Truck	Truck
Quantity	1,000 B/D Avg	1,500 B/D Avg
AREA DISTURBED	559 Acres	214 Acres
NET GROUNDWATER USED	350 AFY	500 AFY
POWER PURCHASED	11 MW	11 MW

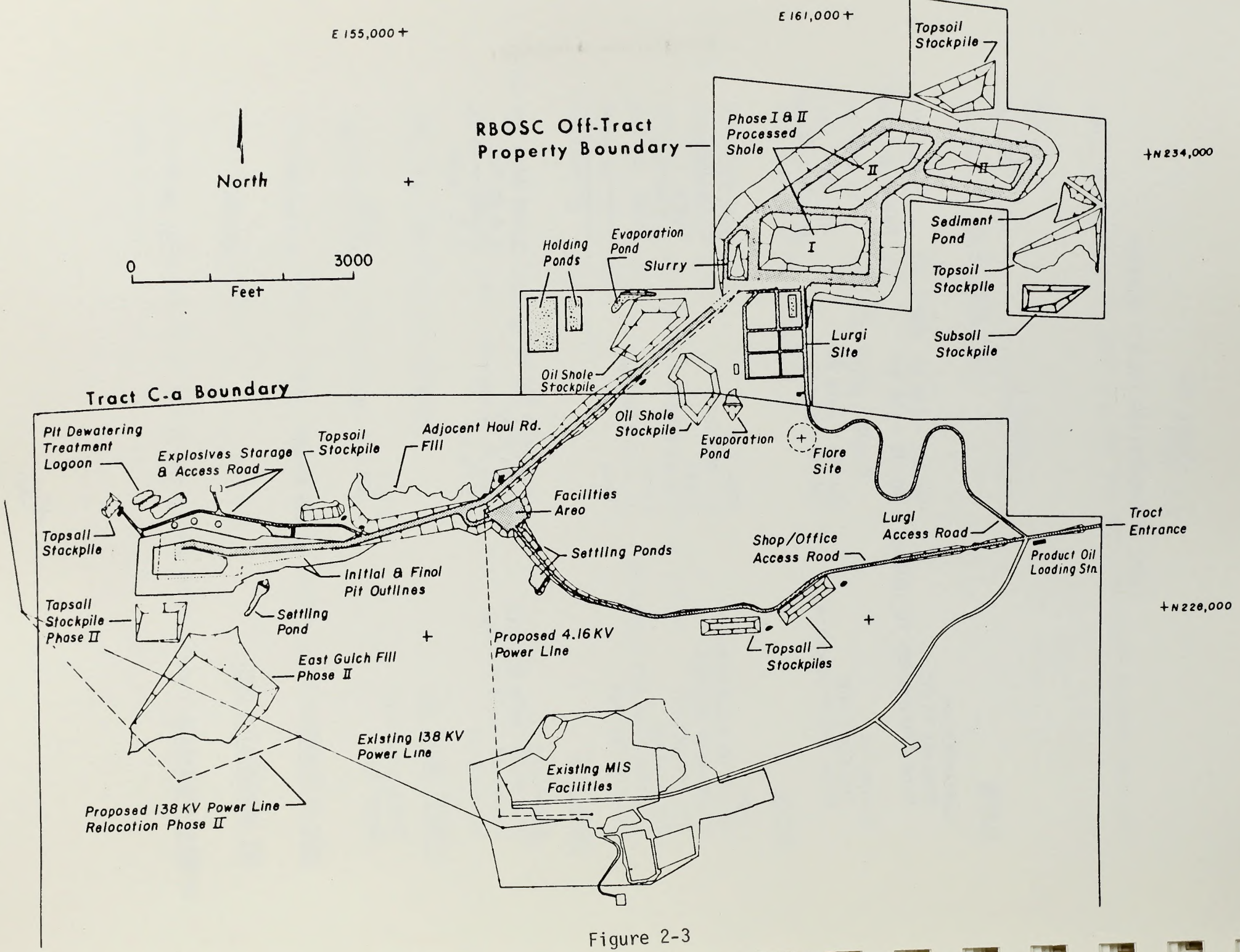

E 155,000 +
E 161,000 +
Topsoil Stockpile
RBOSC Off-Tract Property Boundary
Phase I & II Processed Shale
II
II
I
+N 234,000
North
0
3000
Feet
Holding Ponds
Evaporation Pond
Slurry
Sediment Pond
Topsoil Stockpile
Subsoil Stockpile
Lurgi Site
Oil Shale Stockpile
Tract C-a Boundary
Oil Shale Stockpile
Evaporation Pond
Flare Site
Pit Dewatering Treatment Lagoon
Explosives Storage & Access Road
Topsoil Stockpile
Adjacent Haul Rd. Fill
Facilities Area
Lurgi Access Road
Tract Entrance
Topsoil Stockpile
Settling Ponds
Shop/Office Access Road
Product Oil Loading Stn.
Initial & Final Pit Outlines
Tapsoil Stockpile Phase II
Settling Pond
Proposed 4.16 KV Power Line
+N 228,000
Topsoil Stockpiles
East Gulch Fill Phase II
Existing 138 KV Power Line
Existing MIS Facilities
Proposed 138 KV Power Line Relocation Phase II

Figure 2-3

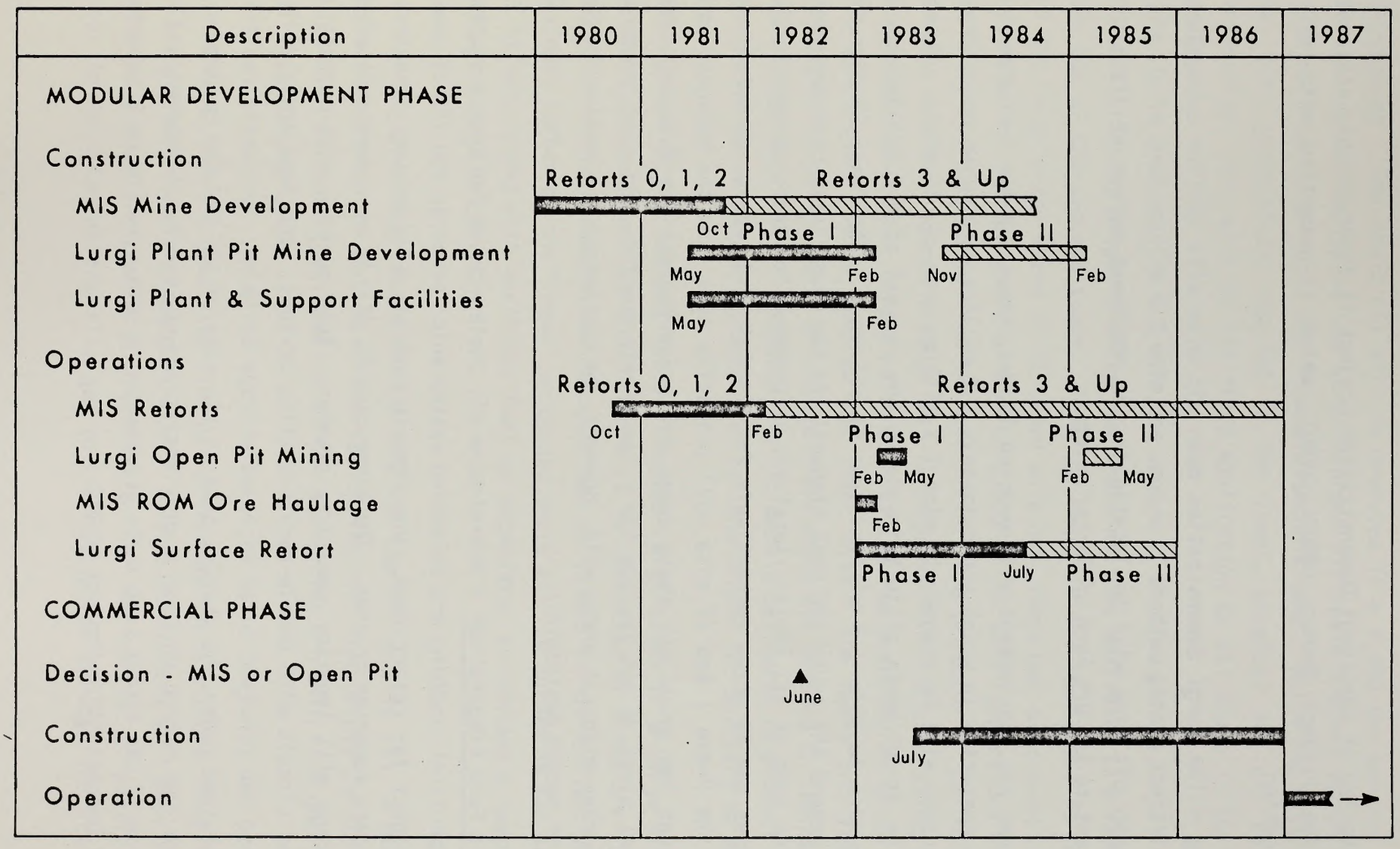


Figure 2-4

RBOSC Construction and Operation Schedule

description of the Lurgi Demonstration Project is found in the Lurgi Demonstration Project Report (RBOSC 1980), which is submitted with this application.

Mining - The Lurgi demonstration open pit mine will utilize conventional shovel/truck mining methods to expose and mine 3.0 million tons of oil shale. The open pit mine will be located in the northwest corner of Tract C-a adjacent to the Dry Fork of Corral Gulch.

The open pit development will proceed in two phases. Phase I will be a 20 month operation in which approximately 5.2 million bank cubic yards (bcy) of overburden will be removed to mine 1.2 million tons of oil shale. Phase II will be an 18 month project involving the removal of 4.2 million bcy of overburden to mine 1.8 million tons of oil shale. The Phase II operation will expand the south and west highwalls of the Phase I pit to expose the 1.8 million tons of oil shale. Total pit disturbance for Phases I and II will be 24 acres and 12 acres respectively for a total of 36 acres. Mined oil shale from the Phase I and II pits will primarily come from the Mahogany zone. Although low grade oil shale zones are present above the Mahogany zone, current plans do not include their use. Their quantity and location in the overburden disposal areas will, however, be engineered and located for later use, if deemed desirable.

Retort Feed Preparation - Run-of-mine oil shale will be fed from a stockpile to a parallel crushing and screening system which prepares 400 TPH of nominal ¼" product for retort feed. One circuit consists of a primary impactor and secondary impactor crusher. The other circuit will be a primary roll crusher and cage mill impactor secondary crusher. Both systems will operate in closed circuit with double-deck vibrating screens. The feed shale will be weighed and conveyed to an enclosed storage building. Automatic reclaiming is provided under the storage pile at the rate of 185 TPH and is sampled and fed to the retort unit by a gravimetric weigh feeder. A schematic flow diagram of the retort feed shale preparation is shown in Figure 3-1-1 of the Lurgi Demonstration Project Report.

Processing - Raw shale oil will be produced in a 4,400 ton per day demonstration plant employing the Lurgi-Ruhrgas Oil Shale Process which has been developed by Lurgi Kohle Und Mineraloltechnik GmbH. While the basic process has been successfully applied in the steel, chemical and oil refining industries, this will be its first application to oil shale in the United States.

In this process, properly sized raw shale will be delivered to a feed bin at the top of the process tower. From the feed bin the feed shale is delivered to the Lurgi mixer where it is mixed with hot, recycled, processed shale and is heated to a temperature of 900 to 1,000°F. At this temperature hydrocarbon vapors are released from the oil shale. The products of the retorting process are then passed through an oil condensation area consisting of three condensation/scrubber towers which recover the raw shale oil in three different fractions - heavy, medium and light oils. The heavy oil fraction contains fine particles of processed shale which are removed in the heavy oil dedusting area. The oil products are ultimately delivered to product storage tanks from which they are transported by tank trucks for delivery to markets.

The mixture of hot solids falls from the Lurgi mixer to a surge bin from which it enters the lift pipe. There it is contacted by a hot air stream of 840°F to initiate combustion of cokes and is lifted to the collecting bin. Residual carbon on the "fresh" processed shale will be burned as the material is lifted, along with auxiliary fuel as necessary, to achieve a temperature of approximately 1,200°F.

As the hot processed shale stream reaches the collecting bin, a measured portion falls to the bottom of the collecting bin, completing the Lurgi loop while the remainder continues out of the collecting bin with flue gas to heat air and generate steam.

In the heat recovery area, the flue gas/processed shale mixture flows through an air preheater and a steam generator. The cooled mixture will pass through cyclones and an electrostatic precipitator for the removal of particulates prior to emission of the flue gas to the atmosphere through the stack. A

schematic diagram of the Lurgi Oil Shale Retort is shown in Figure 4-3-1 of the Lurgi Demonstration Project Report.

The processed shale, which has been collected in several locations, is delivered to a processed shale cooler and then to a moisturizer. From there it goes to a conveying system for transport to the disposal area.

Part of the product gas which exits the condensation area is used as fuel in the lift pipe. The remainder is incinerated after treatment by a venturi-type SO_2 scrubber prior to discharge to the atmosphere by a stack 300 feet above ground level.

Processed Shale and Overburden Disposal - The processed shale and overburden disposal system is designed to demonstrate disposal techniques and to collect pertinent data which will be used to optimize the design and operation for the processed shale disposal system for a commercial operation. The disposal plan for Phase I is based on mining and retorting production schedules. Mining and disposal of overburden is scheduled to begin in September 1981. Disposal of processed shale is scheduled to begin when the demonstration retort is operational and oil shale is fed to the retort. A total of 1.2 million tons of processed shale will be produced in this phase.

Results of laboratory tests of the physical and chemical characteristics of the processed shale and overburden were considered in the design of disposal piles. To demonstrate the physical and chemical stability, permeability and resistance of the processed shale to leaching by water, all processed shale for the demonstration phase will be contained in dikes. All Phase I overburden not needed for road or facilities construction will be used to build the dikes necessary to contain all Phase I processed shale. There will be more than enough overburden available for this purpose, and the excess will be used to start the Phase II containment dike. Side slopes of 3:1 will be used on containment dikes. Finer overburden material will be placed to the inside of the dikes and coarser material to the outside. Before disposing of any processed shale, an impervious liner will be placed inside the dike to allow surface runoff and leachate to be collected for analysis. Several test plots will be set up to analyze various environmental and mining operational

properties of the processed shale such as materials handling, stability of waste, leachate quality, reclamation, erosion and dust control. After the 1.2 million tons of processed shale has been placed in the disposal area and testing completed, the disposal will be reclaimed.

Containment dikes will be revegetated as soon as they are in place. If 3:1 slopes are too steep for effective revegetation, 4:1 slopes will be made by decreasing the width of the top of the containment dike. The processed shale will also be covered with a layer of overburden, topsoiled and revegetated.

The Phase II disposal system design will be based on the results of the Phase I program. The Phase II mine will provide an additional 1.8 million tons of oil shale in the same manner as Phase I. The overburden removed to mine the oil shale will be used to complete the Phase II containment dikes; the remainder will be stored in a gulch area immediately to the southeast of the pit. The overburden stored adjacent to the pit and the spoil used as fill on the haul road and facilities area will be used to backfill the final pit after oil shale removal if the site is abandoned. The processed shale from the Phase II operations will be placed by conveyor within the Phase II containment area. After completion of Phase II oil shale processing and testing, the Phase II containment area dike will be completely reclaimed.

Support Facilities - A wide range of support facilities will be required for the Lurgi Demonstration Project. The most significant of these will be:

- Transportation systems - equipment and materials will be shipped to the project vicinity by rail and the site by truck.

- Electrical Power Supply - the demand for electrical power will be approximately 11 MW which will be supplied from an existing 138/240KV transmission line to Tract C-a which is tied to the Moon Lake Electric Association system. A new 138/23KV substation will be installed near the existing main substation at the MIS facility.

- Product Storage and Transportation - the raw shale oil will be stored in two product storage tanks of 45,000 barrels capacity each. The

produced oil will be piped to a truck loading station near the tract entrance.

- Communications - Mountain Bell Company will provide telephone service from Meeker with sufficient capacity to accomodate intra-project, local and long distance calls. Radio/telephone facilities will satisfy communications during the early phases of construction.

- Fuel and Other Service Products - Diesel fuel, gasoline, lubricating oil, hydraulic fluid and anti-freeze will be distributed in accordance with recommended procedures and stored in appropriate containers for both construction and long term operating requirements.

- Buildings - buildings required for the mine area and the process area will be designed for the service required. Major buildings to house personnel will most likely be of structural steel with precast concrete panels; Explosive Storage and Handling - explosives and blasting agents required for mining and construction will be provided in accordance with applicable State and Federal regulations.

Construction Activities - Construction activities will be coordinated to minimize land disturbance and to avoid unnecessary disturbance. Vehicular traffic will be restricted to established roads, where possible.

Major areas of construction activities are the mine office and shops, haul road between the open pit mine and processing area, the surface retort, processing and support facilities, and the processed shale disposal pile and containment dikes.

Mining and Related Areas - Operations will include the following:

- Clearing and grubbing

- Removal of topsoil

- Removal and use of overburden in the preparation of the haul road

- Access road construction to process area and mine shop/office area

- Preparation of processed shale disposal areas and construction of dikes and holding basins

The operational sequence for mining and related areas is, in general, as follows:

- Mobilization and move-in to commence construction on the access roads to the Shop/Office area where the construction facilities will be located

- Development of the temporary facilities to support the mining operation

- Removal of top soil from the disturbed areas and storage in designated areas

- Removal of overburden from the open mine area and use of this material as fill for the haul road, mine facilities and process area and for constructing the processed shale disposal area

- The removal of the overburden for Phase I operations will continue until approximately the beginning of 1983 when the stockpiling of feed shale will start. The feed shale stockpile will be located near the crusher building of the surface retort demonstration plant

- Various construction activities will phase out in early 1983 but the hauling operation between the mine and the process area will continue as necessary to provide sufficient oil shale for the operation of the processing unit

Processing and Support Facilities - Construction will include the following:

- Clearing and grubbing
- Salvaging top soil and storing in stockpiles
- Site preparation and construction of plant access roads
- On-site concrete preparation using a concrete batch plant
- Constructing facilities to prepare shale for retorting, including facilities for crushing and grinding and transporting
- Lurgi Processing Facility
- Constructing support facilities, including steam, water and fuel supply systems
- Constructing waste water treatment, product off-gas disposal and product storage and transfer systems
- Constructing administrative support facilities such as offices, warehouses, machine shops, fire, safety and communications systems

Construction sequence for the processing and support facilities is, in general, as follows:

- Mobilization and move-in to commence site preparation will begin in May of 1981. Temporary facilities, (water, communications, power, etc.) will be developed to support the construction program. During site preparation, excavation and foundation work will also start for the administration/warehouse and the feed shale storage building with the erection of the buildings to proceed immediately thereafter
- Excavation will be started for the underground firewater system, drainage system and the underground electrical duct work that will carry permanent power to the plant

- During the winter period of 1981/1982, the feed shale storage building will be utiliized as a piping fabrication shop in order to be ready to erect piping during the good weather months of 1982

- Erection of structural steel for the retort process area, crusher building, pipe ways etc. as the foundations are completed

- Grading, earthwork and construction of containment dikes will proceed as practical without conflicting with the mechanical erection of major structures.

- Proceeding with construction of boilers, water treating and waste treatment, product gas incinerator and SO_2 scrubber, and storage tanks as areas are prepared and foundations are completed

- During the erection of structural steel for the retort area, process equipment will be erected in its proper place. The three major process systems within the retort area are distillation, condensation, and waste heat recovery and shale cooling

- The following process equipment that will be erected within the retort area: bins, mixers, cyclones, preheaters, humidifiers, electrostatic precipitator, steam generator, drums, blowers, scrubbers, coolers, tanks, pumps, etc. This equipment will be interconnected with piping, electrical, and instrumentation systems after the equipment is erected.

Other minor buildings will be erected at the Lurgi plant site to house the control room and electrical substation.

During the final months of construction, following hydrostatic testing of systems, insulation of equipment and piping and painting will take place.

Construction activities on the retort, administrative and utility areas will start phasing out in the fall of 1982. Erection equipment will be removed from the site. A general clean-up of the entire area will be performed and

as construction activities diminish, the operation of the plant by permanent employees will start.

2.2.3 Environmental Monitoring - The RBOSC Environmental Monitoring Program for the Lurgi Demonstration Project is designed to 1) fulfill the monitoring stipulations of the Tract C-a Oil Shale Lease, 2) fulfill the monitoring requirements of Federal, State and local permits and 3) evaluate the success of RBOSC environmental protection programs (impact mitigation measures) by assessing the net impacts of the Lurgi Demonstration Project.

Monitoring and/or evaluation programs were developed for air quality, meteorology, terrestrial ecology, aquatic ecology, hydrology, and special studies. A scope of work was developed for each of the programs. These scopes supply detailed information on specific monitoring objectives and development of techniques designed to accomplish these objectives. These scopes were published in a separate document which is on file at RBOSC offices in Denver, at Tract C-a, and with the AOSO.

The RBOSC Air Quality Monitoring Program, initiated in 1975, includes measurements of ambient gaseous constituents and total suspended particulate concentrations. The program is summarized in Table 2-3. Source emissions will also be monitored, but the program has not been developed yet. Extensive discussions will be held with the EPA, CDOH, AOSO and other regulatory agencies to develop an appropriate source emissions monitoring program.

The RBOSC Meteorology Monitoring Program includes measurement of eleven meteorological parameters and specialized studies of area visibility and noise levels. The general meteorological monitoring program is summarized in Table 2-4. The visibility monitoring program, a cooperative effort with Tract C-b, includes both photographic and telephotometric techniques. The program is currently being review to conform to recent EPA Visibility Regulations. Noise levels are monitored quarterly at twenty permanent stations in the project area.

Project Costs - After Gulf and Standard leased Federal Prototype Oil Shale Tract C-a for $210 million, $126 million was paid in cash to the Federal

TABLE 2-3

CURRENT AIR QUALITY MONITORING SCHEDULE

Parameter	Location	Monitoring Dates[1]	Frequency
Sulfur Dioxide	Site 1	Sept. 1977	Continuous
	Site 3	Jan. 1978	Continuous
	Site 7	Fall 1982	Continuous
Hydrogen Sulfide	Site 1	Sept. 1977	Continuous
	Site 3	Jan. 1978	Continuous
	Site 7	Fall 1982	Continuous
Nitric Oxide	Site 1	Sept. 1977	Continuous
	Site 3	Feb. 1980	Continuous
	Site 7	Fall 1982	Continuous
Nitrogen Oxides	Site 1	Sept. 1977	Continuous
	Site 3	Feb. 1980	Continuous
	Site 7	Fall 1982	Continuous
Carbon Monoxide	Site 1	Sept. 1977	Continuous
	Site 3	Jun. 1980	Continuous
	Site 7	Fall 1982	Continuous
Ozone	Site 1	Sept. 1977	Continuous
	Site 3	Nov. 1979	Continuous
	Site 7	Fall 1982	Continuous
Particulates	Sites 1,2,3	Dec. 1977	Every 3rd Day
	Sites 7,8,9	Summer 1981	Every 3rd Day

[1] Indicates date of startup for monitoring exclusive of baseline and interim studies which were conducted from 1975 - 1977.

TABLE 2-4

CURRENT METEOROLOGY STUDIES MONITORING SCHEDULE

Parameter	Location	Monitoring Dates[1]	Frequency
Wind Speed (10 m)	Sites 1,2,3,7[3]	Sept. 1977	Continuous
Wind Direction (10 m)	Sites 1,2,3,7[3]	Sept. 1977	Continuous
Wind Speed (60 m)	Site 1	Sept. 1977	Continuous
Wind Direction (60 m)	Site 1	Sept. 1977	Continuous
Ambient Temperature (10 m)	Sites 1,2,3,7[3]	Sept. 1977	Continuous
Temperature Differential (10-60 m)	Site 1	Sept. 1977	Continuous
Precipitation	Sites 1,2,3,7[3]	Oct. 1977	By event
Barometric Pressure	Site 1	Jan. 1978	Weekly
Solar Radiation	Site 1	Sept. 1977	Continuous
Dew Point (10 m)[2]	Site 1	July 1978	Continuous
Snow Depth & Accumulation	Sites 1,2,3,7[3]	Nov. 1978	By event

[1] Indicates date of startup for monitoring exclusive of baseline and interim studies which were conducted from 1975 - 1977.

[2] Relative humidity data were collected between Sept. 1977 and July 1978

[3] Site 7 to be activated during Summer, 1981

government. RBOSC is currently involved in demonstrating the feasibility of the MIS technology. This demonstration program is completely funded by Gulf and Standard at an estimated cost of $140 million. The Lurgi Demonstration Program consists of three phases - design, construction and operation. The total cost of this program, which will take four to five years, is estimated to be approximately $160 million. This is in addition to the above mentioned costs. At this time, all of these funds will be supplied by Gulf and Standard.

2.2.4 PERMITTING

Although RBOSC has obtained all necessary permits and other regulatory requirements to proceed with construction and operation of the MIS demonstration program, none of these permits are applicable to the Lurgi Demonstration Project. It was thus necessary to determine which specific permits approvals or modifications were required for construction and operations for this project. After these key regulatory requirements were identified, meetings were held with the agencies to review agency requirements and to determine the time needed to review and approve the permit applications to meet the schedule presented in Figure 2-4. The following is a list of the major regulatory requirements and the agencies involved.

Lurgi Demonstration Program Major Regulatory Requirements

Agency	Regulatory Requirement
Area Oil Shale Office	Technical Modification to the Revised Detailed Development Plan
Environmental Protection Agency	Prevention of Significant Deterioration (PSD)
Colorado Dept. of Health/ Air Pollution Control Division	Emissions/Fugitive Dust
Colorado Dept. of Health/ Water Quality Control Division	Surface Discharge (NPDES)
Colorado Dept. of Health/ Radiation and Hazardous wastes Control Division	Processed Shale Disposal Certificate of Designation

Colorado Dept. of Natural Resources Mined Land Reclamation Board	Regular Mining Permit
Rio Blanco County	Special Land Use Permit
Bureau of Land Management	Rights-of-Way/Temporary Use Permit

In order to expedite the permitting process, RBOSC decided to participate in the Joint Review Process in the hope of meeting its proposed schedule for project startup. The Colorado Joint Review Process, developed by the Colorado Department of Natural Resources, is a coordinated, intergovernmental review procedure for major energy and mineral resource developmental projects. The Joint Review Process offered an alternative to traditional project reviews by establishing a management system that coordinates the regulatory reviews of all participating agencies at all levels of government. It is important to note that the Joint Review Process works entirely within established regulatory requirements and does not attempt to alter any existing statutory requirements. It is anticipated that this management system will save RBOSC time and money since it encourages concurrent scheduling of regulatory reviews and approvals rather than the traditional sequential process. The system has shown flexibility to date by acting upon RBOSC's new plans in the midst of its current MIS demonstration.

Sec. 3.0

3.0 DESCRIPTION OF TRACT C-a AND THE PICEANCE BASIN AREA

3.1 Terrain Features - The project site lies on the western side of the Piceance Creek Basin in northwestern Colorado (Figure 3-1). As shown in Figure 3-1, the terrain in the immediate project area is complex, characterized by plateaus, mountain valleys and abrupt changes in elevation. The Piceance Creek Basin is situated between the Colorado and White rivers on the western slope of the Rocky Mountains at an average elevation of about 7,000 feet. The Flat Tops Wilderness Area is situated to the east of the Basin about 80 km from the project area. The White River drains out of the Flat Tops region which encompasses peak elevations reaching to more than 11,000 feet. A high massif, whose streams drain to the Colorado River and its tributaries, lies to the southeast. Piceance Creek itself drains into the White River. The basin is characterized by a series of shallow north-northeast draining valleys. The western edge of the basin is marked by the Cathedral Bluffs, which are relatively steep on their west side. Elevations in the southeastern portion of the Piceance Creek watershed reach 8,000 to 9,000 feet above mean sea level. To the north of the project site are ridges and hills rising to about 7,000 feet. Many geological cuts leading to the Piceance occur throughout the Basin. The complexity of the atmospheric dispersion is directly related to the complexity of the terrain in the region.

3.2 General Climatology - The general climate of the Lurgi Demonstration Project site reflects the complex topography and the weather systems which dominate the area. The Piceance Creek Basin is located in the mid latitude belt of prevailing westerly winds. Severe cold waves are quite rare within the region due to the blocking action of the high mountains of the Continental Divide. Ambient temperatures are moderate during the spring, summer and fall seasons. High pressure areas tend to form over the western slopes of the Colorado Rockies in winter, which result in low nighttime minimum temperatures during winter but abundant sunshine during the day.

During the summer months, the Continental Divide is a very effective barrier preventing moisture transport from the Gulf of Mexico reaching the Piceance Creek Basin (Marlatt, 1973). The average annual precipitation in

the area is approximately 10 to 12 inches, but varies with local topography and elevation. Therefore, the climate of the area has been classified as mountainous semi-arid steppe and is characterized by abundant sunshine, generally low precipitation, low relative humidity and large diurnal and seasonal temperature fluctuations.

Tracts C-a and C-b are separated from the Parachute/Clear Creek area by a minor ridge that runs along an east/west axis (Figure 3-1). In the absence of any significant synoptic systems, air flow is controlled within an airshed by the heating and cooling of local and mesoscale terrain. Therefore the ridge separating the two areas effectively produces two small local airsheds.

3.2.1 Synoptic Meteorological Conditions - The prevailing synoptic winds (unaffected by the terrain of the Piceance Creek Basin) are from the southwest (Meyer and Nelson, 1975). These prevailing synoptic winds are the net result of the interactions of the midlatitude westerlies and the passage of low and high pressure cells. These pressure systems generally move from west to east. However, low pressure cells and storm tracks are usually steered to the north or to the south by the high mountains of the Continental Divide.

Meteorological measurements on plateau areas in the Piceance Creek Basin are primarily affected by the synoptic scale wind flow. Predominant winds on the plateaus are from the south to southwest depending on the particular site. Monitors around Tract C-a indicate predominant winds at C-a are from the west-southwest. Annual average wind speeds at Tract C-a range from about 8 mph to 10 mph. These relatively strong wind speeds are related to the high elevation of the plateau areas and their resultant exposure to the strong synoptic winds.

3.2.2 Canyon and Valley Meteorological Conditions - In the absence of strong gradient flow (i.e., when high pressure cells or weak pressure systems exist over the area) wind flow regimes within canyons and valleys are controlled by surface heating and cooling of the canyon or valley floors and walls. During periods of strong insolation, the laterally

constricted but vertically expanding air, caused by surface heating, tends to flow up the canyon or valley. This flow probably develops simultaneously with anabatic (upslope) winds which result from a greater heating of the sun-facing valley side with respect to the valley floor (Rio Blanco Oil Shale Company, 1977a). At night, drainage winds are very common. Air near the ground is cooled by radiational heat loss. The dry climate and relatively high elevation aids in the area's ability to radiate heat. As this air is cooled it becomes denser and flows downslope. Downward movements of cold air set in motion by this effect form downslope gravity winds, which drain through the valley or canyon bottom. These gravity (or katabatic) winds may be adiabatically compressed slightly as they move downslope because of the increasingly greater mass of atmosphere above them, leading to a temperature increase in the downslope air masses; however, this effect is usually minor.

The Lurgi Demonstration Project site is located on the northeastern side of the local airshed boundary. Katabatic winds drain north to northeast and down the various ravines into the Piceance Creek and Yellow Creek valleys. These in turn drain into the White River Valley.

3.3 Site-Specific Meteorology - Meteorological monitoring has been conducted at four sites near Tract C-a. Figure 3-2 shows the locations of these sites. Sites 1 and 2 are immediately upvalley of the tract, Site 3 is immediately downvalley of the tract and Site 4 is further downvalley of the tract. Monitoring at Sites 1 through 3 has been nearly continuous since February 1975. Monitoring at Site 4 was discontinued in January 1977.

3.3.1 Temperature - Surface air temperature statistics derived from hourly data taken at Site 1 near Tract C-a are summarized in Table 3-1. The data were taken at a height of 10 meters above the ground for the period January 1, 1978 to December 31, 1978.

Average values for a twenty-year period-of-record at Little Hills, which is approximately 25 miles east of and 1,000 feet lower (6,148 ft.) than the project site, are also presented in Table 3-1. Comparison of the data

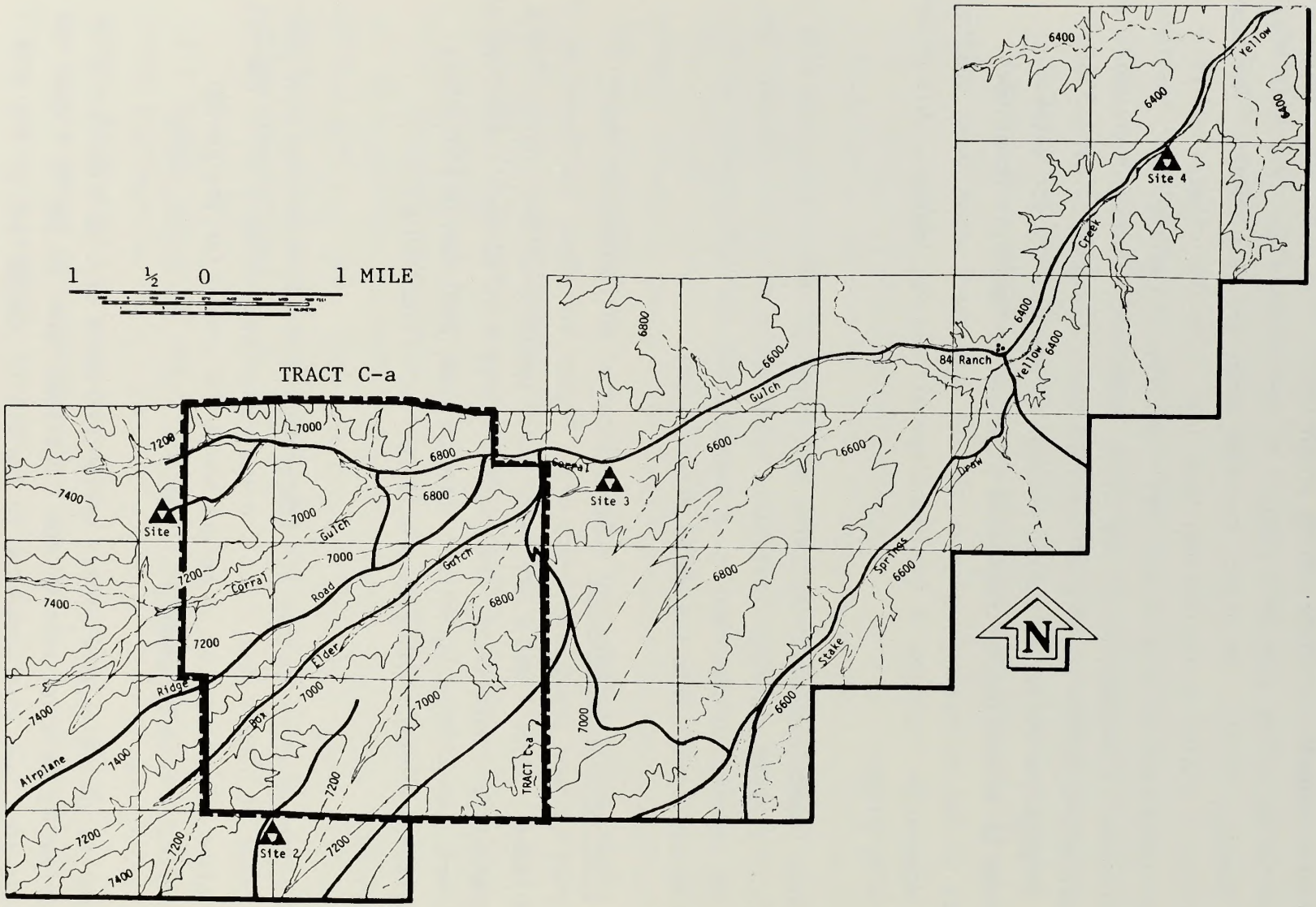


Figure 3-2
TOPOGRAPHIC MAP OF AREA AROUND TRACT C-a SHOWING
LOCATIONS OF METEOROLOGICAL/AIR QUALITY STATIONS

TABLE 3-1

TEMPERATURES (°F) AT MONITORING SITE 1 AND AT LITTLE HILLS, COLORADO

	Project Site 1978				
	Average Maximum	Average Minimum	Hourly Mean	Approximate Data Capture[1] (%)	Little Hills[2] 20-Year Record Mean Temperature
January	30.9	22.0	26.4	90	21.2
February	32.4	22.9	27.3	82	25.6
March	42.4	30.1	36.7	84	31.7
April	48.7	34.5	41.0	77	41.5
May	56.2	39.4	47.7	65	50.7
June	83.5	54.5	64.2	84	58.5
July	77.7	60.1	70.3	65	65.8
August	74.0	55.8	65.8	94	63.7
September	65.8	49.6	57.9	90	55.6
October	58.9	43.9	51.4	71	42.4
November	37.3	26.1	30.2	60	32.6
December	25.0	12.4	18.5	97	23.5

[1]Indicates data capture by day where >3 missing hourly values invalidates the day.

[2]Source: Marlatt (1973).

indicates that the temperatures at Little Hills were lower, despite the lower elevation. This could indicate that the monitoring year at Site 1 was slightly warmer than average or that the exposure of the two stations is different. However, the temperature differences are not substantial.

3.3.2 Mixing Heights - Mixing heights were derived from 1978 monitoring data taken at Site 1 and Grand Junction, Colorado. Site 1 data included wind speed and wind direction from the 60 m height. The data from Grand Junction included temperature sounding information up to 500 millibars. Mixing heights were estimated from the temperature sounding and wind speed data using the scheme developed by Benkley and Schulman (1979). A description of the this technique is provided in Appendix A-5. Table 3-2 lists the average minimum and maximum mixing heights which were derived for the project site. The highest mixing heights occur during sunny spring and summer months when the radiational heating of the earth's surface is at a maximum.

3.3.3 Winds - Figure 3-3 is an annual windrose which was developed from wind speed and direction measurements taken at Site 1 from December 1, 1977 to December 31, 1978. As depicted, the prevailing wind direction is from the southwest and south-southwest. These wind directions occurred approximately 16 and 17 percent of the time, respectively. On the other hand, winds are less likely to reach the site from the east or east-southeast. From these site specific data, the mean annual wind speed was calculated to be approximately 4.71 m/sec (10.5 mph). Table 3-3 presents the mean wind speed values reported by Holzworth (1972) for a five-year period of record at Grand Junction, Colorado. On a seasonal basis, the highest average wind speeds in Grand Junction occur during the spring afternoons and the lowest during the winter mornings. Grand Junction is in a valley and is protected to some extent from the synoptic flow.

3.3.4 Precipitation - Total precipitation recorded at Site 1 from December 1978 to November 1979 is presented in Table 3-4. In addition, 20-year mean values are presented for Little Hills, Colorado, which is approximately 25 miles east of the project site at an elevation of 6,148 feet. On an

TABLE 3-2

AVERAGE MIXING HEIGHTS (m) ESTIMATED FROM ON-SITE AND GRAND JUNCTION DATA

	Average Minimum	Average Maximum
January	138	487
February	133	510
March	145	480
April	154	695
May	182	544
June	175	588
July	200	613
August	172	619
September	151	572
October	172	529
November	123	401
December	148	585

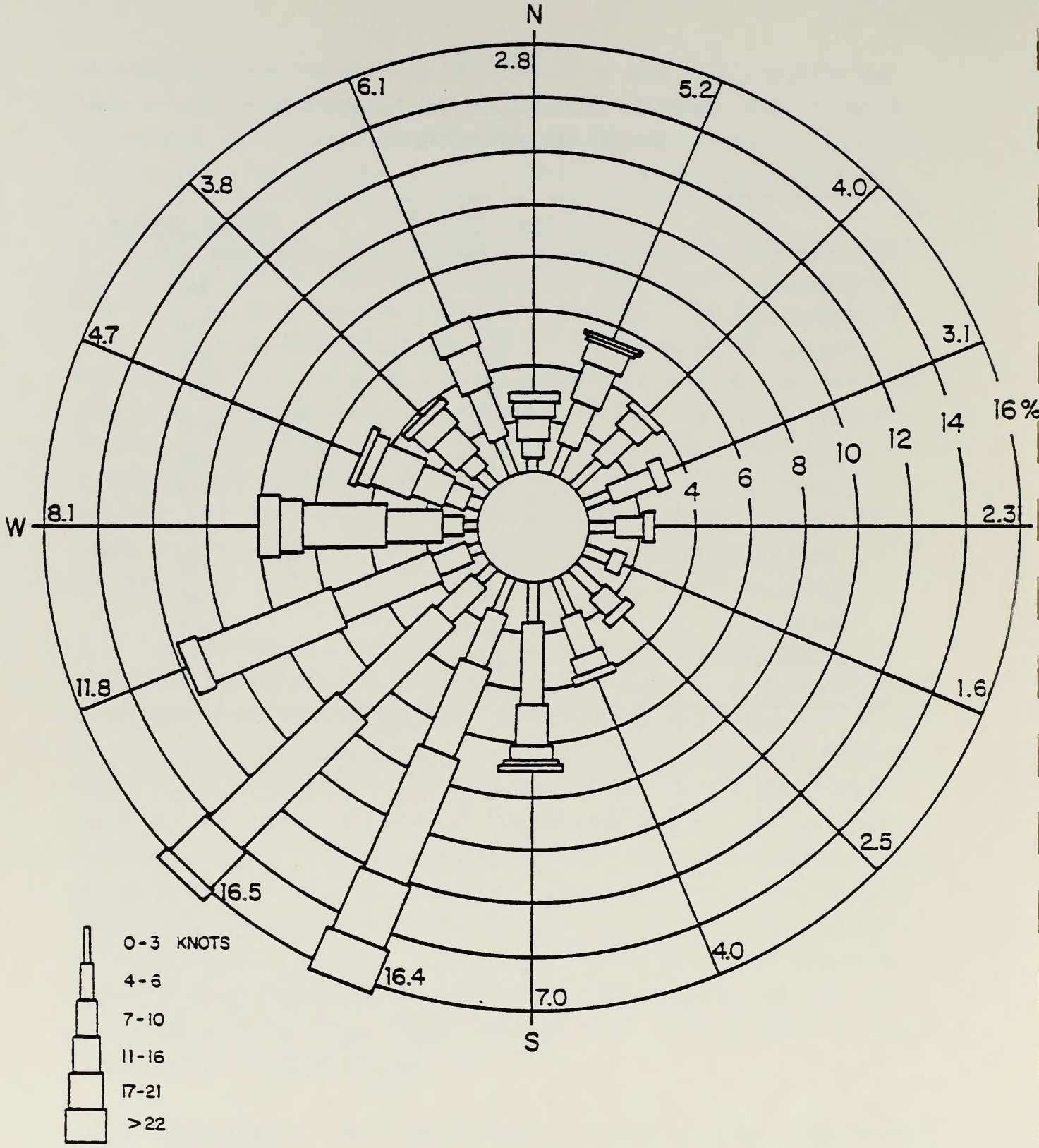


Figure 3-3. Annual Rio Blanco Windrose.

TABLE 3-3

MEAN WIND SPEEDS BY SEASON FOR
GRAND JUNCTION, COLORADO (m/sec)[1]

	Morning	Afternoon
Winter	3.4	3.4
Spring	5.4	6.6
Summer	4.7	6.1
Fall	3.9	4.6
Annual	4.3	5.2

[1]Source: Holzworth (1972)

TABLE 3-4

PRECIPITATION RECORDED AT SITE 1
AND AT LITTLE HILLS

	1979 Total Precipitation At Site 1 (inches)	20-Year Mean at Little Hills[1] (inches)
January	1.14	0.67
February	0.65	0.90
March	1.82	0.95
April	0.85	1.36
May	3.39	1.18
June	0.36	1.10
July	0.77	0.96
August	1.04	1.73
September	0.15	1.16
October	1.83	0.98
November	1.30	0.94
December	1.73	0.97
TOTAL	15.03	12.90

[1]Source: Marlatt 1973.

annual basis, precipitation at Site 1 was slightly greater than the 20-year average value at Little Hills.

3.4 Terrain Effects On Air Quality Impacts - The dispersion of air pollutants can be substantially affected by mountainous or valley and canyon topography. Strong nocturnal drainage flows and early morning fumigation are two typical conditions which can affect maximum ground-level concentrations. However, maximum concentrations due to fumigation are typically short lived (on the order of one-half hour) and should not be conducive to maximum 3-hour and 24-hour impacts. However, pollutants from sources within a canyon, for instance, can be concentrated at ground-level during unstable upslope or slightly stable downslope flow conditions, while plumes originating on plateaus can be entrained into canyon air during nocturnal drainage flow conditions. When studying the dispersion of pollutants in valleys, effects of the diurnal heating cycle must be considered as well as changes in mechanical and thermal turbulence caused by topographic constraints. A discussion of the terrain effects on dispersion in the Piceance Creek Basin is given by Nelson (1975). He found that the combination of topography and gradient flow influences the winds over the basin in two significant ways. First, mechanically generated turbulence is enhanced along the top of the basin itself. Second, the downslope of the basin with increasing downwind distance generates a shielding phenomenon which reduces the gradient wind influence on the surface winds (especially in the valley). This shielding effect slightly raises the degree of mechanical turbulence in the areas above the plateau regions, but probably decreases that present in the valleys (thus making thermally generated turbulence more dominant in them). This is the reason for the predictable diurnal pattern of inversion formation and dissipation within valleys which leads to the nighttime entrainment and daytime fumigation phenomena mentioned above (when significant synoptic systems are not present).

Sec. 4.0

4.0 ANALYSIS METHODOLOGY

The Lurgi Demonstration Project emission sources, other PSD and CDOH permitted oil shale facilities in the Piceance Basin area, the dispersion modeling techniques and assumptions used in this analysis, and the detailed meteorological data used in the modeling computations are discussed below.

4.1 Description of the Tract C-a Emission Sources

The potential emission sources associated with the Lurgi Demonstration Project include the following:

- haul road and access road
- raw shale stockpile
- wind erosion from disturbed areas
- raw shale feed preparation
- Lurgi retort and ancillary process equipment
- support facilities
- processed shale disposal and wind erosion
- hydrocarbon storage tanks

Figure 4-1 (pocket insert) is a general plot plan which shows the locations of the primary emission sources. The Lurgi retort and ancillary process equipment are located in the lower right hand corner of the plant area. Process steam boilers are located in the middle right hand section.

4.1.1 Stack Emissions

The retort flue, incinerator/scrubber, two process steam boilers, and a hot oil heater make up the sources that will emit gaseous effluents under normal operating conditions. A diesel generator, diesel pumps, and flare will emit effluents on a temporary basis during startup, shutdown, or emergency operating conditions. Table 4-1 shows the stack parameters, Universal Transverse Mercator (UTM) coordinates, and estimated emission rates of the various pollutants for the retort flue, incinerator/scrubber,

TABLE 4-1

LURGI AND MIS OPERATIONAL PARAMETERS

Emission Source	Stack Height,m	Exit Temp,°K	Volumetric Flow,m3/s	UTM Coordinates X	Y	Z/ft	SO_2 g/sec	PM g/sec	NO_x g/sec	CO g/sec	HC g/sec	Remarks
Lurgi Operations												
Lurgi Flue	91	523	61.4	715.5	4,421.5	7,120	2.1	5.2	15.2	2.8	0.0	
Product Gas Incinerator/ Scrubber	76	355	30.6	715.5	4,421.5	7,120	1.3	0.0	2.1	0.0	0.0	normal capacity
2 Process Steam Boilers	31	450	28.3	715.5	4,421.5	7,120	0.0	0.0	3.7	0.0	0.0	maximum capacity
Hot Oil Heater	15	755	1.6	715.5	4,421.5	7,120	0.0	0.0	0.1	0.0	0.0	
MIS Operations												
Incinerator/Scrubber	60	353	106.5	715.0	4,424.0	6,600	8.6	1.4	23.0	4.7	0.8	normal capacity
Process Steam Boiler	30	450	14.8	715.0	4,424.0	6,600	2.1	0.1	5.2	0.1	0.04	normal capacity

and process steam boilers. Similar parameters for the Modified In Situ (MIS) retort, which may be in operation at the same time, are also shown. Detailed descriptions of the Lurgi project site and process facilities appear in Section 4, Chapters 2 and 3 of RBOSC's Lurgi Demonstration Project Report which was submitted with the permit application. The MIS operations are briefly discussed in Section 4.1.3 below.

4.1.2 Fugitive Dust Emissions

The open pit oil shale mine, haul road and access roads, raw shale stockpile, overburden disposal, raw shale feed preparation, and processed shale disposal are the primary fugitive dust sources. The following is a brief description of the mining operations. Refer to Figure 4-1 (pocket insert) for the locations of the various sources. A more detailed description of these activities is given in Sections 2, 3, and 5 of the Development Plan.

The target construction start date is May 1, 1981, with a four-month construction phase. During that time, the shop/warehouse complex for the mining operations will be constructed, access roads will be completed, most topsoil will be stripped and stockpiled, and production equipment will be mobilized.

Overburden stripping operations will commence about September 1, 1981 and will continue for a four-month period. The initial overburden will be used as fill material for constructing the lower portion of the haul road and the mine/shop facilities area. The balance of the overburden will be used to begin construction of dikes in the area to the northeast of the Lurgi operations. These dikes will contain the processed shale produced in 1983 and the first half of 1984.

Continued overburden stripping, topsoil removal and construction of the dikes in the processed shale disposal area are the primary activities scheduled for 1982.

Operations in 1983 include additional overburden and topsoil removal for the Phase II pit, removal of oil shale for Phase I operations, oil shale stockpiling and feedstock preparation (crushing and grinding), and processed shale transfer from the Lurgi retort area to the processed shale disposal area.

In 1984, operations will include continued overburden removal from the Phase II pit, production of oil shale for Phase II operations, topsoil removal from the Phase II dike and east gulch fill areas, oil shale stockpiling and feedstock preparation (crushing and grinding) and processed shale transfer from the retort to the processed shale disposal area.

Emissions from construction-related activities need not be considered in determining consumption of PSD increments for TSP because these are temporary and short-term activities. Construction-related emissions must be considered, however, in determining compliance with Colorado Ambient Air Quality Standards (CAAQS). Tables 4-2 through 4-6 list the short term and long term emission rates categorized by those that contribute to consumption of PSD increment and those that contribute to total atmospheric loadings of TSP (relative to the CAAQS).

Emission factors were based on EPA Region VIII guidelines (1979), Colorado Department of Health guidelines (1979), Wyoming Department of Environmental Quality quidelines (1979), EPA AP-42 (1977), and information obtained in various meetings with representatives of EPA Region VIII and the Colorado Department of Health. Operational parameters and dust control techniques reflect the current mining plan. Appendix B contains the detailed calculations, process by process, with references to the appropriate documents used to arrive at the final emission rates.

As shown in Tables 4-2 through 4-6, the highest total short term and annual emission rates that contribute to PSD increment consumption will occur in 1983. Fugitive dust emissions from 1983, therefore, were modeled with the ERT MINE model to determine consumption of the 24-hour and annual Class II PSD TSP increments. The highest total short term emission rate that contributes to total atmospheric loadings of TSP, relative to the CAAQS,

TABLE 4-2

TRACT C-a LURGI DEMONSTRATION PROJECT FUGITIVE DUST INVENTORY

CONSTRUCTION PHASE-MAY 1981 THROUGH AUGUST 1981

Fugitive Dust Source	Emission Factor	Operational Parameter	Control Technique	Percent Control	NAAQS Emission Rate[2]		PSD Emission Rate[2]	
					g/sec	ton/4mos	g/sec	ton/4 mos
Topsoil Removal	0.38 lb/yd^3	505,700 yd^3/4 mos	watering	50	5.81	48.04	0.56	4.61
Topsoil Haul	0.703 lb/VMT	12,800 VMT/4 mos	watering	50	0.27	2.25	0.03	0.22
Water Truck Traffic	1.22 lb/VMT	3,480 VMT/4 mos	watering	50	0.13	1.06	0.00	0.00
Access Road Traffic[1]	3.05 lb/VMT	311 VMT/day	90% compaction	80	1.00	4.13	0.50	2.07
Access Road Construction[1]	32 lb/grader-hr	520 grader hrs/ 4 mos	watering	50	1.01	4.16	0.00	0.00
Topsoil Erosion	0.0712 tons/ acre-yr	40 acres	rapid vegetation	75	0.08	0.24	0.08	0.24
Concrete Batch Plant								
sand and aggregate transfer to elevated bins	0.04 lb/ton	268.5 ton/day	baghouse	99	0.00	0.00	0.00	0.00
cement unloading to elevated storage silos	0.23 lb/ton	41.5 ton/day	baghouse	99	0.00	0.00	0.00	0.00
weight hopper loading of cement, sand, and aggregate	0.23 lb/ton	310 ton/day	baghouse	99	0.00	0.03	0.00	0.00
mixer loading of cement, sand, and aggregate	0.02 lb/ton	310 ton/day	baghouse	99	0.00	0.00	0.00	0.00
loading of transit mix truck	0.02 lb/ton	324 ton/day	none	0	0.04	0.28	0.00	0.00
Topsoil Dumping	0.03 lb/yd^3	505,700 yd^3/4 mos	watering	50	0.46	3.80	0.04	0.36
TOTAL					7.80	63.99	1.21	7.50

[1] These two operations cannot occur simultaneously. The total short term emissions reflect access road construction.

[2] Controlled emission data

TABLE 4-3

TRACT C-a LURGI DEMONSTRATION PROJECT FUGITIVE DUST INVENTORY
OVERBURDEN STRIPPING PHASE-SEPTEMBER 1981 THROUGH DECEMBER 1981

Fugitive Dust Source	Emission Factor	Operational Parameter	Control Technique	Percent Control	NAAQS Emission Rate[2]		PSD Emission Rate[2]	
					g/sec	ton/4mos	g/sec	ton/4 mos
Overburden Removal	0.0069 lb/ton	4,557,390 ton/ 4 mos	none	0	1.90	15.72	1.34	11.07
Overburden Haul	1.64 lb/VMT	69,615 VMT/4 mos	LS[1]	85	1.04	8.61	0.00	0.00
Water Truck Traffic	1.22 lb/VMT	1,740 VMT/4 mos	LS[1]	85	0.03	0.29	0.00	0.00
Access Road Traffic	3.05 lb/VMT	311 VMT/day	90% compaction & LS[1]	80 & 85	0.15	1.24	0.08	0.62
Overburden Dumping	0.02 lb/ton	4,557,390 ton/ 4 mos	none	0	5.51	45.57	0.00	0.00
Haul Road Construction	32 lb/grader-hr	1,577 grader hr/ 4mos	watering	50	1.75	12.62	0.00	0.00
Concrete Batch Plant								
sand and aggregate transfer to elevated bins	0.04 lb/ton	268.5 ton/day	baghouse	99	0.00	0.00	0.00	0.00
cement unloading to elevated storage silos	0.23 lb/ton	41.5 ton/day	baghouse	99	0.00	0.00	0.00	0.00
weight hopper loading of cement, sand, and aggregate	0.23 lb/ton	310 ton/day	baghouse	99	0.00	0.03	0.00	0.00
mixer loading of cement, sand, and aggregate	0.02 lb/ton	310 ton/day	baghouse	99	0.00	0.00	0.00	0.00
loading of transit mix trucks	0.02 lb/ton	324 ton/day	none	0	0.04	0.28	0.00	0.00
Drilling	1.5 lb/hole	675 holes/mo	water injection	90	0.02	0.20	0.02	0.20
Blasting	50 lb/blast	17 blast/mo	none	0	0.20	1.69	0.20	1.69
Topsoil Erosion	0.0712 tons/ acre-yr	40 acres	rapid vegetation	75	0.08	0.24	0.08	0.24
Overburden Erosion	0.0576 tons/ acre-yr	71 acres	none	0	0.12	1.36	0.12	1.36
Disturbed Areas Erosion	0.0576 tons/ acre-yr	301 acres	none	0	0.50	5.78	0.50	5.78
TOTAL					11.34	93.63	2.34	20.96

1/ LS - Lignon Sulfonate or other dust palliative
2/ Controlled emissions

TABLE 4-4

TRACT C-a LURGI DEMONSTRATION PROJECT FUGITIVE DUST INVENTORY

1982 OPERATIONS

Fugitive Dust Source	Emission Factor	Operational Parameter	Control Technique	Percent Control	NAAQS Emission Rate[2/] g/sec	NAAQS Emission Rate[2/] ton/yr	PSD Emission Rate[2/] g/sec	PSD Emission Rate[2/] ton/yr
Overburden Removal	0.0069 lb/ton	6,015,200 ton/yr	none	0	0.84	20.75	0.84	20.75
Overburden Haul	1.65 lb/VMT	247,038 VMT/yr	LS[1/]	85	1.23	30.57	0.00	0.00
Overburden Dumping	0.02 lb/ton	6,015,200 ton/yr	none	0	2.42	60.15	0.00	0.00
Topsoil Removal	0.38 lb/yd^3	252,500 yd^3/yr	watering	50	0.97	23.99	0.00	0.00
Topsoil Haul	0.703 lb/VMT	6,391 VMT/yr	LS[1/]	85	0.01	0.34	0.00	0.00
Topsoil Dumping	0.03 lb/yd^3	252,500 yd^3/yr	watering	50	0.08	1.90	0.00	0.00
Access Road Traffic	3.05 lb/VMT	311 VMT/day	90% compaction & LS[1/]	80 & 85	0.15	3.71	0.12	2.97
Water Truck Traffic[3/]	1.22 lb/VMT 0.49 lb/VMT	5,220 VMT/yr 10,440 VMT/yr	LS[1/]	85	0.03	0.86	0.00	0.00
Drilling	1.5 lb/hole	675 holes/mo	water injection	90	0.02	0.61	0.02	0.61
Blasting	50 lb/blast	17 blasts/mo	none	0	0.20	5.07	0.20	5.07
Concrete Batch Plant								
sand and aggregrate transfer to elevated bins	0.04 lb/ton	268.5 ton/day	baghouse	99	0.00	0.00	0.00	0.00
cement unloading to elevated storage silos	0.23 lb/ton	4.15 ton/day	baghouse	99	0.00	0.00	0.00	0.00
weight hopper loading of cement, sand, and aggregate	0.23 lb/ton	310 ton/day	baghouse	99	0.00	0.12	0.00	0.00
mixer loading of cement, sand, and aggregate	0.02 lb/ton	310 ton/day	baghouse	99	0.00	0.00	0.00	0.00
loading of transit mix truck	0.02 lb/ton	324 ton/day	none	0	0.04	0.85	0.00	0.00

TABLE 4-4 (CONTINUED)

TRACT C-a LURGI DEMONSTRATION PROJECT FUGITIVE DUST INVENTORY

1982 OPERATIONS

Fugitive Dust Source	Emission Factor	Operational Parameter	Control Technique	Percent Control	NAAQS Emission Rate 2/		PSD Emission Rate 2/	
					g/sec	ton/4mos	g/sec	ton/4 mos
Topsoil Erosion	0.0712 ton/ acre-yr	60 acres	rapid vegetation	75	0.03	1.07	0.03	1.07
Overburden Erosion	0.0576 tons/ acre-yr	167 acres	none	0	0.28	9.56	0.28	9.56
Disturbed Areas Erosion	0.0576 tons/ acre-yr	301 acres	none	0	0.50	17.34	0.50	17.34
TOTAL					6.80	176.89	1.99	57.37

1/ LS - Lignon Sulfonate or other dust palliative

2/ Controlled emissions as applicable

3/ Two different sizes of water trucks will be used

TABLE 4-5

TRACT C-a LURGI DEMONSTRATION PROJECT FUGITIVE DUST INVENTORY

1983 OPERATIONS

Fugitive Dust Source	Emission Factor	Operational Parameter	Control Technique	Percent Control	NAAQS Emission Rate[2/]		PSD Emission Rate[2/]	
					g/sec	ton/yr	g/sec	ton/yr
Overburden Removal	0.0069 lb/ton	2,483,600 yd^3/yr	none	0	0.63	15.64	0.63	15.64
Overburden Haul	1.65 lb/VMT	25,481 VMT/yr	LS[1/]	85	0.13	3.15	0.04	0.87
Overburden Dumping	0.02 lb/ton	2,483,600 yd^3/yr	none	0	1.83	45.33	1.61	39.98
Topsoil Removal	0.38 lb/yd^3	16,900 yd^3/yr	watering	50	0.06	1.61	0.06	1.61
Topsoil Haul	0.703 lb/VMT	414 VMT/yr	LS[1/]	85	0.00	0.02	0.00	0.02
Topsoil Dumping	0.03 lb/yd^3	16,900 yd^3/yr	Watering	50	0.01	0.13	0.01	0.13
Ore Removal	0.000069 lb/ton	1,200,000 ton/yr	none[3/]	0	0.00	0.04	0.00	0.04
Ore Haul	1.65 lb/VMT	41,332 VMT/yr	LS[1/]	85	0.21	5.12	0.21	5.12
Ore Dumping	0.000069 lb/ton	1,200,00 ton/yr	none[3/]	0	0.00	0.04	0.00	0.04
Water Truck Traffic	1.22 lb/VMT 0.49 lb/VMT	5,220 VMT/yr 10,440 VMT/yr	LS[1/]	85	0.03	0.86	0.03	0.86
Access Road Traffic	3.05 lb/VMT	311 VMT/day	90% compaction & LS[1/]	80 & 85	0.15	3.71	0.15	3.71
Topsoil Erosion	0.0712 tons/ acre-yr	60 acres	rapid revegetation	75	0.03	1.07	0.03	1.07
Overburden Erosion	0.0576 tons/ acre-yr	167 acres	rapid revegetation	75	0.07	2.39	0.07	2.39
Ore Stockpile Erosion	0.00758 tons/ acre-yr	29 acres	none	0	0.01	0.22	0.01	0.22
Ore and Overburden Drilling	1.5 lb/hole	675 holes/mo	water injection	90	0.02	0.61	0.02	0.61
Ore and Overburden Blasting	50 lb/blast	17 blast/mo	stemming in wet holes	50	0.10	2.54	0.10	2.54
Disturbed Areas Erosion	0.0576 ton/ acres-yr	301 acres	none	0	0.50	17.34	0.50	17.34
Run of Mine Ore Load Out From Ore Stockpile	0.0011 lb/ton	4,400 ton/day	none	0	0.03	0.44	0.03	0.44
Run of Mine Ore Load In to Primary Crusher Hopper	0.0022 lb/ton	4,400 ton/day	none	0	0.05	0.88	0.05	0.88

TABLE 4-5 (CONTINUED)

Fugitive Dust Source	Emission Factor	Operational Parameter	Control Technique	Percent Control	NAAQS Emission Rate[2] g/sec	NAAQS Emission Rate[2] ton/year	PSD Emission Rate[2] g/sec	PSD Emission Rate[2] ton/yr
Primary Crushing/Screening	0.12 lb/ton	4,400 ton/day	baghouse	99	0.03	0.48	0.03	0.48
Secondary Crushing/Screening	0.16 lb/ton	4,400 ton/day	baghouse	99	0.04	0.64	0.04	0.64
Crushed Ore Conveying to Stockpile Building	0.20 lb/ton	4,400 ton/day	baghouse	99	0.05	0.80	0.05	0.80
Crushed Ore Load Out From Stockpile Building	0.05 lb/ton	4,400 ton/day	baghouse	99	0.01	0.20	0.01	0.20
Crushed Ore Conveying to Feed Hopper Upstream of Belt Conveyer	0.20 lb/ton	4,400 ton/day	baghouse	99	0.05	0.80	0.05	0.80
Crushed Ore Transfer to Lurgi Feed Hopper Via Belt Conveyer	0.20 lb/ton	4,400 ton/day	baghouse	99	0.05	0.80	0.05	0.80
Processed Shale Transfer Via Rotary Feeder and Conveyor	0.20 lb/ton	4,400 ton/day	baghouse	99	0.05	0.80	0.05	0.80
Processed Shale Transfer From Hopper to Processed Shale Disposal Area	0.20 lb/ton	4,400 ton/day	baghouse	99	0.05	0.80	0.05	0.80
Processed Shale Disposal Via Stacker in Processed Shale Disposal Area	0.20 lb/ton	4,400 ton/day	moisturized processed shale	90	0.46	8.03	0.46	8.03
Processed Shale Erosion	0.0576 tons/acre-yr	30 acres	chemical bonding of wet spent shale	none	0.05	1.73	0.05	1.73
TOTAL					4.70	116.22	4.39	108.59

[1]LS - Lignon Sulfonate or other dust palliative

[2]Controlled emissions

[3]No specific controls are planned. However, the ore is associated with an aquifer and will be saturated with water

TABLE 4-6

TRACT C-a LURGI DEMONSTRATION PROJECT FUGITIVE DUST INVENTORY

1984 OPERATIONS

Fugitive Dust Source	Emission Factor	Operational Parameter	Control Technique	Percent Control	NAAQS Emission Rate[2/] g/sec	NAAQS Emission Rate[2/] ton/yr	PSD Emission Rate[2/] g/sec	PSD Emission Rate[2/] ton/4 mos
Overburden Removal	0.0069 lb/ton	1,957,000 yd^3/yr	none	0	0.50	12.32	0.50	12.32
Overburden Haul	1.65 lb/VMT	108,530 VMT/yr	LS[1/]	85	0.54	13.43	0.00	0.10
Overburden Dumping	0.02 lb/ton	1,957,000 yd^3/yr	none	0	1.44	31.28	0.18	4.44
Topsoil Removal	0.38 lb/yd^3	253,100 yd^3/yr	watering	50	0.97	24.05	0.35	8.64
Topsoil Haul	0.703 lb/VMT	5,821 VMT/yr	LS[1/]	85	0.01	0.31	0.00	0.11
Topsoil Dumping	0.03 lb/yd^3	253,100 yd^3/yr	Watering	50	0.08	1.70	0.03	0.68
Ore Removal	0.000069 lb/ton	1,800,000 ton/yr	none[3/]	0	0.00	0.06	0.00	0.06
Ore Haul	1.65 lb/VMT	61,998 VMT/yr	LS[1/]	85	0.31	7.67	0.31	7.67
Ore Dumping	0.000069 lb/ton	1,800,000 ton/yr	none[3/]	0	0.00	0.06	0.00	0.06
Water Truck Traffic	1.22 lb/VMT 0.49 lb/VMT	5,220 VMT/yr 10,440 VMT/yr	LS[1/]	85	0.03	0.86	0.03	0.86
Access Road Traffic	3.05 lb/VMT	311 VMT/day	90% compaction & LS[1/]	80 & 85	0.15	3.71	0.15	3.71
Topsoil Erosion	0.0712 tons/ acre-yr	60 acres	rapid revegetation	75	0.03	1.07	0.03	1.07
Overburden Erosion	0.0576 tons/ acre-yr	167 acres	rapid revegetation	75	0.07	2.39	0.07	2.39
Ore Stockpile Erosion	0.00758 tons/ acre-yr	43 acres	none	0	0.01	0.33	0.01	0.33
Ore and Overburden Drilling	1.5 lb/hole	675 holes/mo	water injection	90	0.02	0.61	0.02	0.61
Ore and Overburden Blasting	50 lb/blast	17 blast/mo	stemming in wet holes	50	0.10	2.54	0.10	2.54
Disturbed Areas Erosion	0.0576 ton/ acres-yr	301 acres	none	0	0.50	17.34	0.50	17.34
Run of Mine Ore Load Out From Ore Stockpile	0.0011 lb/ton	4,400 ton/day	none	0	0.03	0.44	0.03	0.44
Run of Mine Ore Load In to Primary Crusher Hopper	0.0022 lb/ton	4,400 ton/day	none	0	0.05	0.88	0.05	0.88

TABLE 4-6 (CONTINUED)

Fugitive Dust Source	Emission Factor	Operational Parameter	Control Technique	Percent Control	NAAQS Emission Rate[2] g/sec	NAAQS Emission Rate[2] ton/yr	PSD Emission Rate[2] g/sec	PSD Emission Rate[2] ton/yr
Primary Crushing/Screening	0.12 lb/ton	4,400 ton/day	baghouse	99	0.03	0.48	0.03	0.48
Secondary Crushing/Screening	0.16 lb/ton	4,400 ton/day	baghouse	99	0.04	0.64	0.04	0.64
Crushed Ore Conveying to Stockpile Building	0.20 lb/ton	4,400 ton/day	baghouse	99	0.05	0.80	0.05	0.80
Crushed Ore Load Out From Stockpile Building	0.05 lb/ton	4,400 ton/day	baghouse	99	0.01	0.20	0.01	0.20
Crushed Ore Conveying to Feed Hopper Upstream of Belt Conveyer	0.20 lb/ton	4,400 ton/day	baghouse	99	0.05	0.80	0.05	0.80
Crushed Ore Transfer to Lurgi Feed Hopper Via Belt Conveyer	0.20 lb/ton	4,400 ton/day	baghouse	99	0.05	0.80	0.05	0.80
Processed Shale Transfer Via Rotary Feeder and Conveyor	0.20 lb/ton	4,400 ton/day	baghouse	99	0.05	0.80	0.05	0.80
Processed Shale Transfer From Hopper to Processed Shale Disposal Area	0.20 lb/ton	4,400 ton/day	baghouse	99	0.05	0.80	0.05	0.80
Processed Shale Disposal Via Stacker in Processed Shale Disposal Area	0.20 lb/ton	4,400 ton/day	moisturized processed shale	90	0.46	8.03	0.46	8.03
Processed Shale Erosion	0.0576 tons/acre-yr	30 acres	chemical bonding of wet spent shale	none	0.05	1.73	0.05	1.73
TOTAL					5.68	136.13	3.20	79.33

[1] LS - Lignon Sulfonate or other dust palliative

[2] Controlled emissions

[3] No specific controls are planned. However, the ore is associated with an aquifer and will be saturated with water

occurs in 1981. The highest total long term emission rate, relative to the CAAQS, occurs in 1982. These two periods were also modeled with the ERT MINE model to determine compliance with the 24-hour and annual CAAQS.

4.1.3 Hydrocarbon Emissions

The Lurgi Demonstration Project will produce some hydrocarbon emissions from various petroleum storage facilities and transfer operations. Table 4-7 delineates these sources and the estimated hydrocarbon emissions. The hydrocarbon emissions were not modeled because of the low emission rates and because there is no generally accepted method for modeling reactive pollutants. Assumptions and detailed calculations of the hydrocarbon emissions are given in Appendix C.

4.1.4 MIS Operations

As stated in 4.1.1, it is conceivable, although unlikely, that the MIS retort will operate concurrently with the Lurgi demonstration retort. Figure 4-1 (pocket insert) shows the location of the various MIS operations associated with a shale oil production of up to 1,000 bbl/day. The stack emission sources include an incinerator/scrubber and a process steam boiler.

Stack parameters and emission rates from the MIS operations are delineated in Table 4-1. These were included in the modeling analysis to represent a worst case situation. The flare stack only operates during upset or shutdown conditions, and thus was not included in the modeling.

4.2 Other Significant Emission Sources

The Cathedral Bluffs Oil Shale Company currently has a PSD permit for a 5,000 bbl/day MIS facility at Tract C-b. There are two stack emission sources, the Stretford thermal oxidizer and a process steam boiler. For modeling purposes, weighted average stack parameters were calculated for one stack based upon the SO_2 emission rates from each separate stack. These weighted average stack parameters are shown in Table 4-8.

TABLE 4-7

PROJECTED HYDROCARBON EMISSIONS
LURGI DEMONSTRATION PROJECT

Facility Description	Hydrocarbon Emissions (lb/hr)
Product Storage Tank	1.82
Product Storage Tank	1.82
Product Oil Loading Station	0.90
Diesel Fuel Storage	0.13
Diesel Fuel Day Tank	0.04
Diesel Fuel Day Tank	0.04
Diesel Unloading Station	0.08
Gasoline Storage	0.05
Waste Oil Storage	0.08
TOTAL	4.96 lb/hr
	21.7 tons/year

TABLE 4-8

OPERATIONAL PARAMETERS OTHER PSD SOURCES

Emission Source	Stack Height,m	Exit Temp,°K	Volumetric Flow,m^3/s	UTM Coordinates X	Y	Z/ft	SO_2 g/sec	PM g/sec	NO_x g/sec	CO g/sec	HC g/sec
C-b MIS-5,000 bbl/day	30	477	143.5	739.8	4,408.7	6,800	3.5	5.0	56.2	488.4	3.1
Colony - 46,000 bbl/day	77	381	42.2	747.2	4,388.5	7,500	41.4	32.1	220.0	8.7	38.2
Union Oil - 10,000 bbl/day	52	769	61.5	751.5	4,386.7	7,200	12.8	27.2	11.1	16.4	5.5

The Colony Development Corporation has a PSD permit for a 46,000 bbl/day surface retort and underground mine. The primary emission sources associated with Colony's operation include reheat stacks, elutriators, a sulfur plant, hydrogen furnaces, a gas oil reboiler, and a coker feed heater. Weighted average stack parameters for this source are shown in Table 4-8.

The Union Oil Company has a PSD permit for a 10,000 bbl/day modular surface retort and underground mine. There are two main emission sources, a recycle gas heater and a steam boiler. The weighted average stack parameters for this source are shown in Table 4-8.

Paraho has a PSD permit for a 4,700 bbl/day facility to be located near Anvil Points (see Figure 3-1). Occidental Petroleum has a PSD permit for a series of experimental retorts (~1,000 bbl/day) located in the Logan Wash area (see Figure 3-1). Because of to their small size and distance from Tract C-a, their emissions were not modeled.

4.3 Selection of Appropriate Models

Federal and State laws require any new development with the potential to affect air quality to conduct an analysis of expected air quality impacts. Such an analysis must reflect not only the expected emissions from the proposed development but also the existing air quality and meteorological conditions in the area. The analysis, therefore, involves the collection of data to characterize existing conditions and the utilization of a mathematical representation of atmospheric behavior (model) to calculate expected pollutant concentrations resulting from plant emissions.

The most important criteria in selecting an appropriate model is the available data base. Even though a sophisticated modeling approach may be warranted, the lack of sufficient data may make such an approach inappropriate. The size of the impacted region, the terrain and its influence on the meteorological conditions, and the presence of other nearby emission sources, which also must be modeled, are other important considerations in model selection.

4.3.1 Modeling Considerations for the Tract C-a Sources

The Lurgi Demonstration Project is complex from an air quality modeling perspective. Within the overall project area are many individual sources of pollutant emission, each with their own emission characteristics (stack heights, exit temperatures, etc.). The project also includes a surface mining operation with ground-level sources of fugitive dust. In addition, there are numerous other emission sources near the project area.

The analytical models utilized to simulate the dispersion of emissions from project sources were based on the Gaussian-plume formulation (Turner, 1969). Several factors were considered in selecting the modeling approach. It is desirable to estimate the air quality impact in the immediate vicinity of the project. It is also desirable to estimate impacts in the region surrounding the project including PSD Class I areas. While certain sources, such as the elevated stacks, have the potential to impact remote receptors, other sources, such as the mining operations, are expected to primarily impact the immediate project area. For elevated stacks, a prime modeling consideration is the plume interaction with nearby terrain. For the mining emissions, however, the pollutants are released at ground-level and maximum impacts are not likely to result from interaction with terrain.

The models used for simulating the dispersion of pollutants from the elevated sources are designed specifically for treating plume behavior as it is affected by interaction with terrain. These models are a special version of the EPA VALLEY Model (Sequential VALLEY) and the ERT Multiple Point Source Diffusion Model (MPSDM). These models were also utilized to calculate concentrations at the Flat Tops Wilderness area (PSD Class I), located roughly 80 kilometers to the east of Tract C-a. For the mining sources, the ERT MINE model with the deposition treatment of Ermak (1977) was utilized. Each of these models and their application to the C-a Tract are discussed briefly below. More detailed descriptions of the models can be found in Appendix A.

4.3.2 Elevated Stack Modeling

The dispersion of emissions from elevated stacks at Tract C-a was determined by applying two models:

- a modified version of the EPA VALLEY model, called Sequential VALLEY, developed by ERT, and

- the Multiple Point Source Diffusion Model (MPSDM), also developed by ERT

These models are similar except for the difference in treatment of plume and terrain interaction. Sequential VALLEY is based on the EPA VALLEY model, but rather than using the standard meteorological assumption for calculating maximum 3-hour and 24-hour concentrations (6 hours of persistent stable, low wind speed conditions), Sequential VALLEY calculates concentrations for every hour of an entire year of meteorological data and then generates consecutive 3-hour and 24-hour averages for the year. The Sequential VALLEY model assumes that during stable conditions the plume is allowed to approach the terrain to a point where the plume centerline is 10 meters above the terrain height. During unstable or neutral conditions the plume is assumed to maintain its original height above the terrain.

MPSDM, however, goes a step further and incorporates the concept of variable terrain correction. That is, the plume is only allowed to approach the terrain to a minimum distance equal to a fraction (called the plume height correction) of the initial plume height (stack height plus plume rise). The MPSDM modeling was performed subsequent to the Sequential VALLEY modeling in order to allow utilization of the Sequential VALLEY model results to determine appropriate values for the plume height correction parameter to be used in MPSDM. The plume height correction parameter was determined by examining the meteorological conditions which produced the maximum Sequential VALLEY concentrations, and then computing the hill Froude number for those meteorological conditions. The hill Froude number represents the ratio of the inertial forces of a moving body of air (which would carry it over the hill) to the gravitational forces (which would

cause it to impinge on the hill and then travel around the hill to the side).

The highest terrain in the vicinity of the proposed Lurgi plant is the western boundary of the airshed, which runs generally north/south along the top of the Cathedral Bluffs, and then to the southeast and east, just to the north of the Colony and Union property boundaries (see Figure 3-1). The portion of this high terrain that is closest to Tract C-a is the Cathedral Bluffs, which is approximately 8 kilometers from the Tract at its nearest point. The highest concentrations from elevated plumes during stable conditions should occur on the highest terrain. Therefore, it was assumed, in laying out the receptor grid for the Sequential VALLEY modeling, that the highest concentrations under stable conditions would occur in the Cathedral Bluffs area.

The potential for stable impingement of the various plumes from Tract C-a sources was assessed by examining the detailed meteorological conditions associated with the five highest predicted 3-hour SO_2 concentrations from the Sequential VALLEY modeling. According to the fluid modeling studies of Hunt et al., (1978) air parcels (or plumes) will preferentially flow directly onto the high terrain (impingement) and then flow around it if the parcels (as identified by plume height) are below a fluid streamline referred to as the dividing streamline height (DSH). This impingement situation is conducive to maximum ground level pollutant concentrations. However, plumes above the DSH will preferentially flow over the terrain obstacle with lesser groundlevel pollutant impact. The DSH is calculated with the following equations (Hunt et al., 1978):

$$DSH = h_T(1-F_R), \text{ and}$$

$$F_R = \frac{\bar{u}}{h_T}\left(\frac{g}{Ta} \cdot \frac{d\Theta}{dz}\right)^{-\frac{1}{2}} \quad \text{where}$$

F_R = hill Froude number. This nondimensional parameter is essentially a measure of the vertical inertia of a horizontally advecting parcel of air (or plume) as it

encounters a high terrain obstacle, as compared to the gravitational forces which tend to prevent the parcel from rising.

h_T = height of the terrain obstacle relative to the stack base

$\bar{u}$ = average wind speed of the advected plume

g = acceleration due to gravity

Ta = ambient temperature

$\frac{d\Theta}{dz}$ = vertical potential temperature gradient in the layer of air from stack base to h_T. This is used as a surrogate for the density gradient.

Table 4-9 shows the five highest 3-hour SO_2 concentrations from the Sequential VALLEY modeling and the associated receptors in the Cathedral Bluffs area. Table 4-10 lists the pertinent hourly meteorological conditions; hill Froude number; DSH; and plume heights for effluents from the Lurgi flue gas stack, the Lurgi incinerator/scrubber, and the Tract C-a MIS incinerator/ scrubber. All plume heights in Table 4-10 are greater than the corresponding DSH values. Therefore, according to the fluid modeling studies of Hunt et al., (1978), the Tract C-a plumes should flow over Cathedral Bluffs without direct impingement, even during worst-case, stable 3 hour impact (as determined by the more conservative Sequential VALLEY model). The results of this analysis also indicate that all elevated plumes in the Piceance Creek Basin (including the plumes from Tract C-b operating at 5,000 bbl/ day) should flow over all the high terrain of the airshed boundary without direct impingement for the following reasons:

1) The Cathedral Bluffs portion of the airshed boundary is generally higher than other portions of the boundary. If elevated plumes flow over this terrain, they can be expected to behave similarly with respect to lower terrain obstacles.

TABLE 4-9

FIVE HIGHEST 3-HOUR SO_2 CONCENTRATIONS
SEQUENTIAL VALLEY MODELING

ulian Day	SO_2 Concentration, $\mu g/m^3$	Receptor Number	Location [1,2]	MSL Elevation, ft.
347	65.1	82	W	7,000
45	62.0	82	W	7,000
292	57.3	91	SW	7,200
350	56.4	42	NW	7,400
292	53.5	82	W	7,400

See Figure 4-1 in Section 4.1.1 for the exact locations of the receptors.

Location with respect to tract boundary.

TABLE 4-10

HOURLY METEOROLOGICAL PARAMETERS FOR FIVE HIGHEST 3-HOUR SO_2 CONCENTRATIONS

Julian Day	h_T, m[1]	$\bar{u}$, m/s	$\frac{d\theta}{dz}$, °K/m	Fr	DSH, m	Plume Height[1], m		
						Lurgi Flue Gas	Lurgi Scrubber	MIS Scrubber
347	122	1.1	0.0378	0.248	92	343	297	154
		0.7	0.0398	0.154	103	358	306	167
		0.6	0.0338	0.143	104	371	314	179
45	122	0.9	0.0078	0.447	67	426	348	230
		1.3	0.0078	0.645	43	405	335	210
		0.9	0.0078	0.447	67	426	348	230
292	183	0.4	0.0158	0.093	166	433	352	236
		0.5	0.0158	0.116	162	419	343	223
		0.5	0.0158	0.116	162	419	343	223
350	244	1.5	0.0058	0.432	138	413	340	218
		0.9	0.0038	0.320	166	476	378	276
		0.7	0.0038	0.249	183	497	391	295
292	122	0.4	0.0158	0.140	105	433	352	236
		0.5	0.0158	0.174	101	419	343	223
		0.5	0.0158	0.174	101	419	343	223

[1] These heights are relative to the stack base of the MIS incinerator/scrubber, i.e., 6,600 ft. MSL. The base elevation of the Lurgi flue gas and scrubber stacks is 7,120 ft. MSL.

2) The plume from the stack at C-b (associated with 5,000 bbl/day production) has a much higher volumetric flux and generally higher exit temperature than the C-a plumes (See Tables 4-1 and 4-6). Therefore, under identical meteorological situations, it will have a higher calculated plume height than the C-a plumes.

The results and conclusions discussed above were used to specify the appropriate plume height corrections, as a function of atmospheric stability, for the MPSDM modeling. When the plumes flow preferentially over high terrain during stable atmospheric conditions, a plume height correction factor of 0.35 (Hoffnagle 1977 and Slowik 1973) was used to adjust the plume centerline height above the terrain. This correction can be explained by the following two constraints which are imposed on plume behavior:

1) For downwind receptors where the terrain elevation is less than the effective stack height (stack height plus plume rise), the plume centerline height (above terrain) is set at 35% of the difference in height between the downwind receptor and the stack base, and

2) for downwind receptors where the terrain height is greater than the effective stack height, the plume centerline height is set at 35% of the effective stack height.

MPSDM model calculations for flow under neutral atmospheric conditions were based on the analysis by Egan (1975) of a plume embedded in a potential flow approaching a terrain object, which indicated that a half height correction to the Gaussian formula would provide an estimate of the peak ground-level concentrations expected. This 0.5 plume height correction factor was also utilized for unstable conditions in the MPSDM modeling.

4.3.3 Modeling of Mining Operations

The ground-level fugitive dust sources were modeled using a recently developed version of the ERT MINE Model. MINE is a multi-source model, capable of treating point sources, area sources, and line sources in a

sequential mode. That is, each hour of meteorological data is analyzed separately and 24-hour average concentrations are calculated.

The MINE model is designed specifically for modeling mining sources. The only pollutant treated is particulate matter, all of which is assumed to be emitted at or near ground-level. There is no treatment for plume rise incorporated in the MINE model. The model does, however, contain a detailed treatment for particle deposition using the deposition equation of Ermak (1977). This routine is based on a theoretical solution of the differential equations which describe atmospheric diffusion. It contains a removal mechanism for particulates by both gravitational settling and turbulent diffusion to the surface with subsequent removal by impaction. The latter mechanism uses the particle deposition velocity and is judged to be of greater importance in the removal of small particles due to the low emission release height and the very low gravitational settling velocity.

Particles were divided into five particle size classes and each class modeled with a separate value for the deposition and gravitational settling velocity. The particle sizes represented by each class and the deposition and gravitational settling velocities utilized for each class are shown in Table 4-11. The gravitational settling velocities were calculated from Stokes Law, assuming a particle density of 2 grams per cubic centimeter, while the deposition velocities were selected from the curves of Sehmel and Hodgson (1974). Since the primary mechanism for deposition of small particles is turbulent diffusion to the ground and removal by impaction, the degree of turbulence in the atmosphere is of key importance. To utilize the curves of Sehmel and Hodgson, it is necessary to specify a value for the surface roughness length, a parameter based on the terrain complexity, vegetation and buildings in the area considered. For the fugitive dust modeling a value of 5 centimeters was selected as the surface roughness length. This value is probably conservatively low as suggested by the method of Smedman-Högström and Högström (1978).

TABLE 4-11

KEY DEPOSITION PARAMETERS USED IN THE MINE MODELING

Particle Size Class	Range of Particle Sizes (μm)	Characteristic Particle Size (μm)	Percentage in[1]/ Each Particle Size Class	Gravitational[2]/ Settling Velocity (cm/sec)	Deposition[3]/ Velocity (cm/sec)
1	0-1	0.5	19%	0.0	0.8
2	1-2.0	1.5	5%	0.0	1.2
3	2.0-3.3	2.7	5%	0.014	1.5
4	3.3-7.0	5.0	8%	0.15	2.0
5	>7.0	15.0	63%	1.35	7.0

1/ This particle size distribution was assumed and is based on ERT (1980).

2/ Based on Stokes law for particles of spherical size and diameter equal to the characteristic particle size. Also, the density of the particles was assumed to be 2 g/cm^3.

3/ Calculated from the curves of Sehmel and Hodgson (1974) for a surface roughness length of 5 cm.

4.3.4 Modeling of Visibility Impacts

The project is not anticipated to have any significant impact on visibility. The presence of a PSD Class I area in the regional study area (the Flat Tops Wilderness Area), however, makes it necessary to insure that visibility impairment will not occur.

In May of 1980, the EPA issued a draft version of a workbook for estimating visibility impairment (EPA 1980). Included in the workbook is a screening procedure for determining whether a particular source has the potential to affect visibility. This screening procedure was utilized in this study to estimate whether the proposed project will impair visibility in the Flat Tops Wilderness Area. This is discussed in more detail in Section 6 herein.

4.3.5 Modeling of Secondary Growth Emissions

It is recognized that the regional growth associated with the Lurgi Demonstration Project will result in some emissions to the atmosphere. It is neither practical nor necessary to individually model each of these sources in an air quality analysis. Instead, a rough estimate of the level of air quality impact resulting from these emissions can be obtained by a simplified box model analysis. In such an analysis, the emissions are assumed to emanate uniformly from the surface of a large box. The volume of the box is effectively determined by the length of one side, the mixing height, and the wind speed. No material is diffused in or out of the box, rather only clean air ventilates the box and pollutants are conveyed out of the box by the wind. The pollutants within the box are assumed to be completely mixed. The length of the side is selected to be representative of the area where the emissions are being generated.

4.4 Meteorological Data Used In Model Analysis

One year of on-site meteorological data was used in this study as input to the modeling analysis. The data were collected from a 60 meter tower located at Site 1 of the RBOSC meteorological monitoring network. The data

included wind speed, wind direction, and temperature at two heights, 60 meters and 10 meters. In addition, the modeling analysis required the specification of other parameters, specifically mixing height and atmospheric stability. As discussed in Section 3, the mixing heights were developed using the on-site wind data and upper atmospheric soundings from Grand Junction, Colorado. A method for estimating mixing heights from these data has been developed by Benkley and Schulman (1979). A description of this method is contained in Appendix A.

Atmospheric stability was estimated using the wind speed and temperature data from Site 1. The method used in this study for characterizing each hour of meteorological data into one of the Pasquill stability classes involves first calculating a parameter called the Monin-Obukhov length. A discussion of the technique has been presented in Appendix A.

Using the on-site data and the techniques described above, a sequential list of meteorological input parameters for each hour was developed.

Sec. 5.0

5.0 CONSUMPTION OF PSD INCREMENTS

The air quality analysis discussed in this document was conducted to comply with Part C of the Clean Air Act in determining the consumption by the Lurgi Demonstration Project of Class I and II PSD increments. At present, PSD increments have only been established for sulfur dioxide (SO_2) and total suspended particulates (TSP). Table 5-1 shows the appropriate PSD increments for Class I and Class II areas. Tract C-a is in a Class II area. As seen in this Table, there are two sets of values for each pollutant and averaging time. The Class I increments refer to the levels applicable in areas of special air quality concern, such as National Parks and Wilderness areas. The only nearby Class I area is the Flat Tops Wilderness, located about 80 kilometers east of Tract C-a.

The 3-hour and 24-hour PSD increments are not to be exceeded more than once per year. In conducting an analysis to determine if a proposed project will result in increases in ambient concentrations of SO_2 and TSP, all other new sources of emissions that have been permitted since the date of the first PSD permit in the area must be accounted for. Thus, the modeling includes not only those sources associated with the projects at Tract C-a, but also those at Tract C-b, the Colony Oil Shale Project and the Union Oil Shale Project.

The discussion in this Section includes the impacts calculated for both SO_2 and TSP.

5.1 Consumption of SO_2 Increment

The impacts of the project on ambient SO_2 concentrations were analyzed using the elevated point source models, Sequential VALLEY and MPSDM (see Cahpter 4 and Appendix A). The Sequential VALLEY Modeling was performed first.

TABLE 5-1

PSD INCREMENTS in $\mu g/m^3$

Pollutant	Class I	Class II
Sulfur dioxide (SO_2)		
3-hour	25	512
24-hour	5	91
annual	2	20
Total Suspended Particulate (TSP)		
24-hour	10	37
annual	5	19

5.1.1 Class II Areas

Sequential VALLEY

Sequential VALLEY computes concentrations at receptors specified by the user for every hour of the year of meteorological record. The hourly concentrations are then averaged for each 3-hour and 24-hour period to determine the peak short-term concentrations. An annual average value is also calculated by averaging all hourly concentrations over the entire year. One of the purposes for running Sequential VALLEY was to determine the concentrations of pollutants during stable conditions on high terrain near Tract C-a, specifically the Cathedral Bluffs to the west of the project area. The proper selection of input parameters for the MPSDM modeling was determined by analyzing the Sequential Valley impacts and establishing the meteorological conditions under which maximum short-term concentrations occur. Consequently, most of the receptors selected for the Sequential VALLEY modeling were to the west of the project area as shown in Figure 5-1. The remaining receptors were located in the Flat Tops Wilderness area. Modeling results at these receptors will be discussed in the next section.

The results of the Sequential VALLEY modeling are presented here both in graphical and tabular form. Table 5-2 presents a summary of the highest and second highest 3-hour, 24-hour, and annual-average concentrations calculated by the model. As shown in the table, model results are given for the Lurgi project alone and the Lurgi combined with the other identified regional sources of SO_2. Table 5-2 also shows that all predicted concentrations are below the Class II PSD increments for SO_2. The highest and second highest 3-hour concentrations both resulted from stable, low wind speed meteorological conditions with the wind directed to the west towards Cathedral Bluffs. The same is true of the maximum 24-hour values. These results indicate that stable, low wind speed conditions directed at nearby high terrain may cause the greatest air quality impacts due to emissions from the C-a elevated stacks.

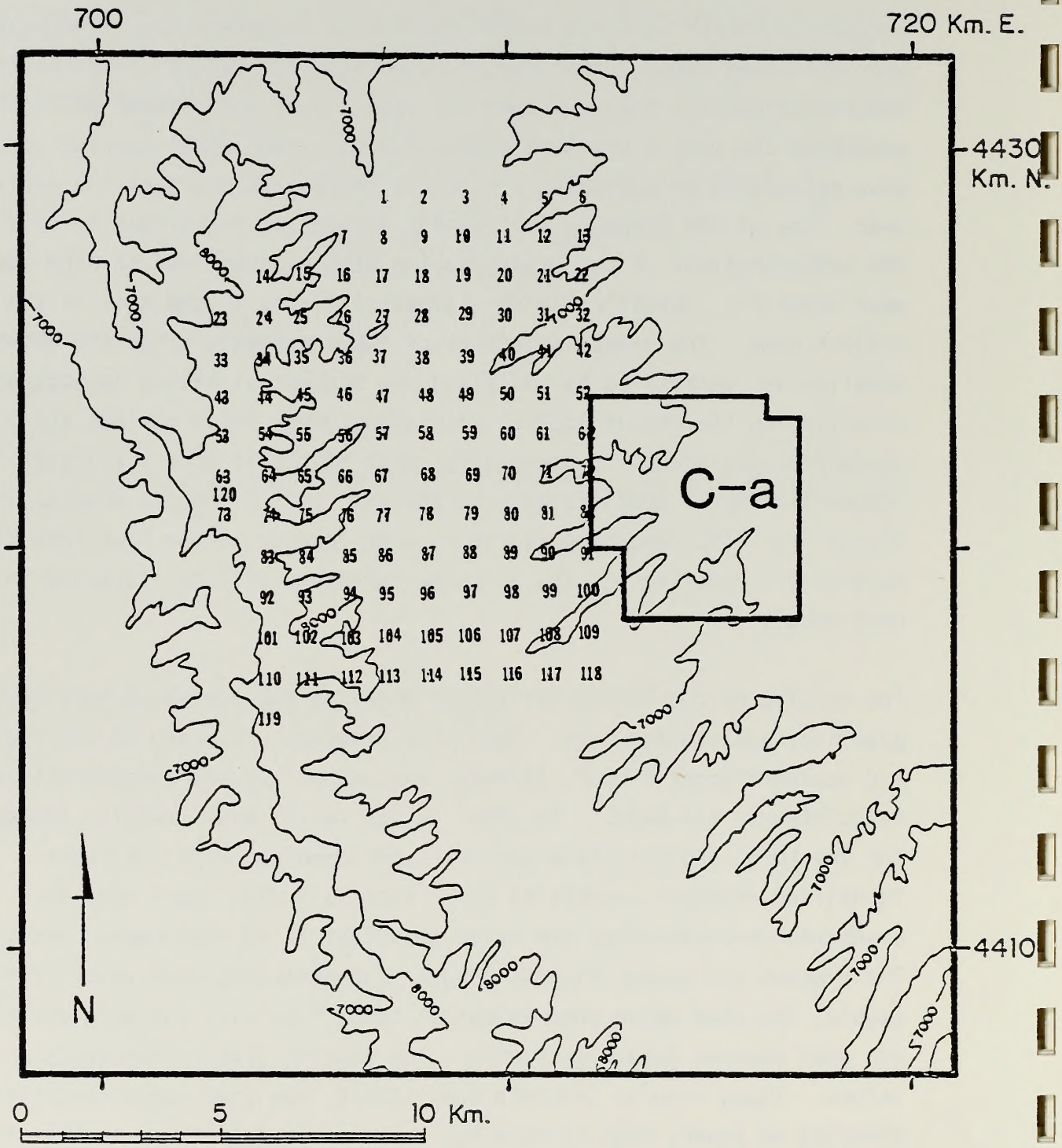


Figure 5-1 Receptor Layout for the Sequential VALLEY Modeling. (See Figure 5-5 for receptors in Flat Tops Wilderness Area.)

TABLE 5-2

SUMMARY OF MAXIMUM SO_2 CONCENTRATIONS CALCULATED BY SEQUENTIAL VALLEY FOR CLASS II AREAS

	Maximum SO_2 Concentration		Second Maximum SO_2 Concentration		Class II PSD
Tract C-a Alone	Value ($\mu g/m^3$)	Receptor	Value ($\mu g/m^3$)	Receptor	Increment ($\mu g/m^3$)
3-hour	65.1	82	62.0	82	512
24-hour	22.9	91	22.3	82	91
All Sources					
3-hour	65.1	82	62.0	82	512
24-hour	23.1	91	22.4	82	91
annual	2.0	72	1.5	82	20

Model results shown in Table 5-2 indicate that the ground level pollutants at Cathedral Bluffs are almost entirely due to the C-a sources alone. The combined concentrations from Tract C-a with other sources in the area are only slightly greater than those of C-a alone. This results from the proximity of Tract C-a to the critical receptors.

The spatial distribution of Sequential VALLEY modeling results for Tract C-a sources alone is shown in Figures 5-2, 5-3, and 5-4. Figure 5-2 is a plot of annual average isopleths of SO_2 concentration. Figures 5-3 and 5-4, however, are not isopleths per se but are plots of the maximum SO_2 concentration at each receptor for the 3-hour and 24-hour averaging times. Since these concentrations do not necessarily occur at each receptor during the same averaging period, the figures are called "zones of influence" rather than isopleths. As the figures depict, the concentrations are low and are confined to a small area.

Using the Sequential VALLEY modeling results, appropriate values for the plume height correction factor were selected and used in the MPSDM modeling. See Section 4.3.2.

MPSDM

The MPSDM modeling was performed over a much wider area than the Sequential VALLEY modeling. New receptor sites were selected and are shown in Figure 5-5. The objectives of the MPSDM modeling differed from the Sequential VALLEY modeling in that not only were potential impacts on the high terrain immediately to the west of Tract C-a considered, but also the entire air shed within and surrounding the Piceance Creek Basin. The MPSDM modeling, as with Sequential VALLEY, was performed in a sequential mode; that is, concentrations were calculated for every hour of data in the meteorological record and used to calculate 3-hour and 24-hour averages from which the maximums were determined. Also annual-average concentrations were calculated by averaging all of the hourly concentrations.

A summary of the results obtained is shown in Table 5-3. All predicted concentrations are well below the Class II increment for SO_2. The MPSDM

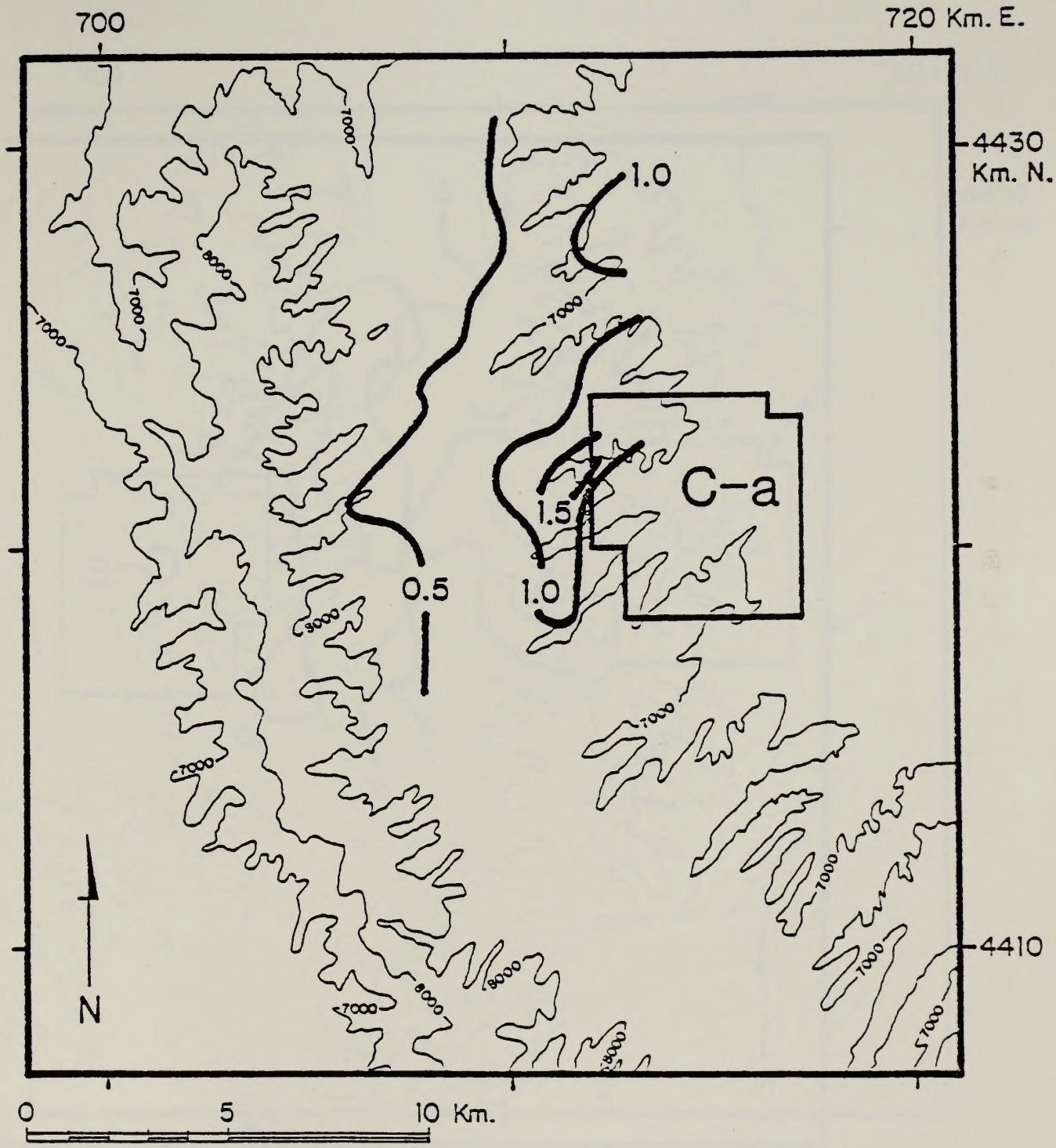


Figure 5-2 Predicted Annual Sequential VALLEY SO_2 Isopleths ($\mu g/m^3$) from C-a Sources as predicted by the Sequential Valley model.

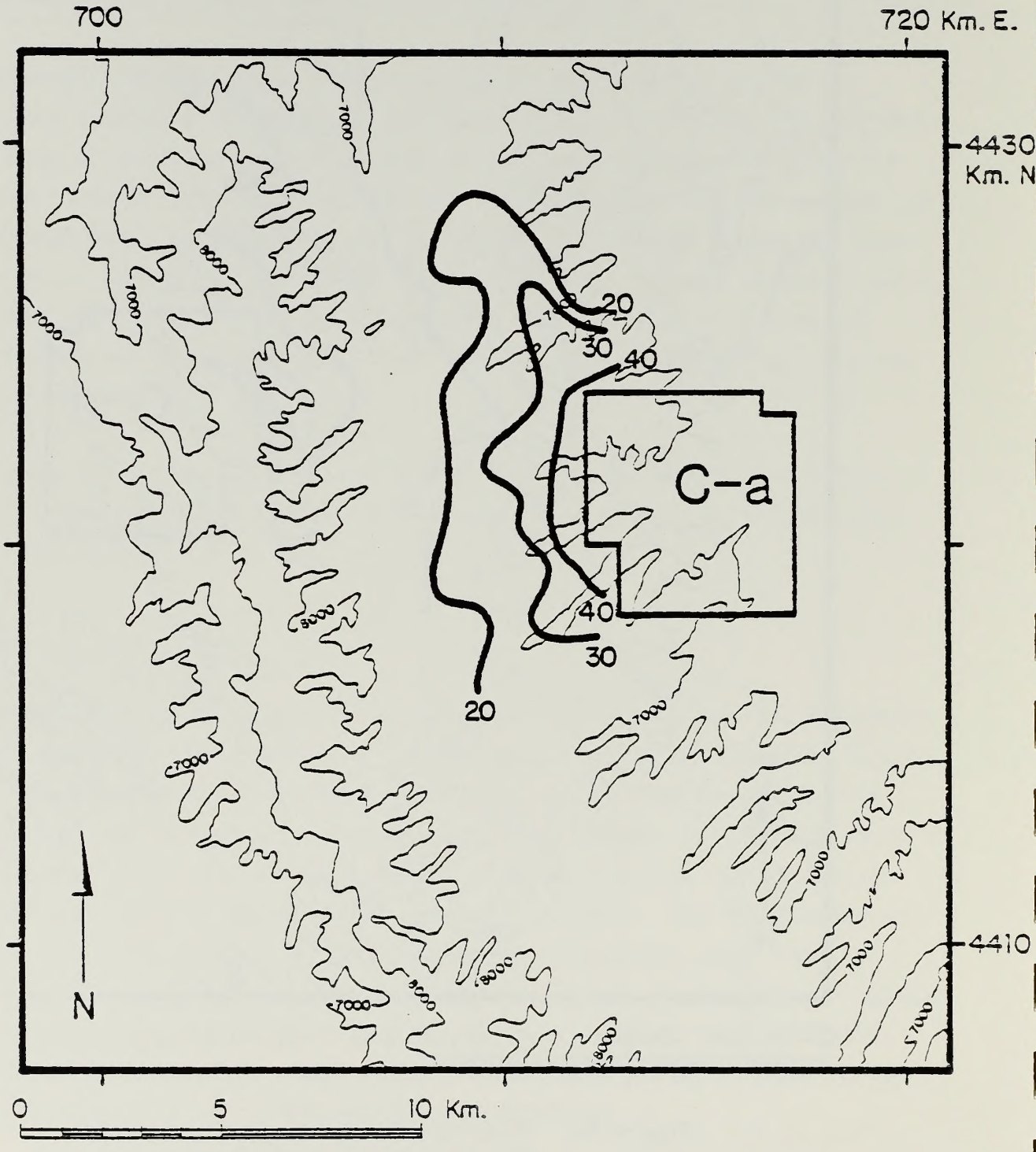


Figure 5-3. Zones of Influence Showing the Maximum 3-hour SO_2 Concentrations in $\mu g/m^3$ at each point as calculated by Sequential VALLEY for C-a sources alone.

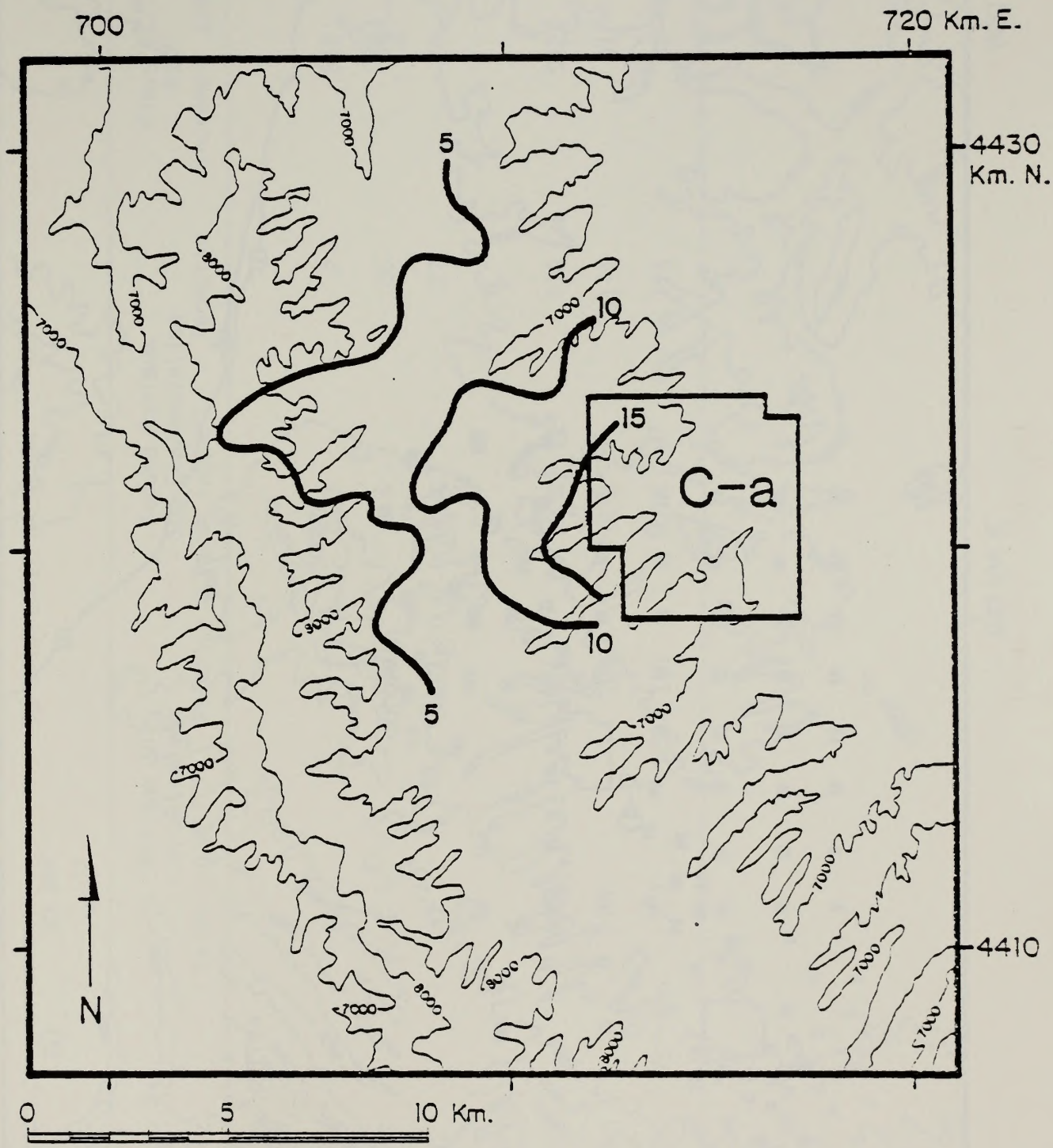


Figure 5-4. Zone of Influence Showing the Maximum 24-hour SO_2 Concentrations in $\mu g/m^3$ at each point as calculated by Sequential VALLEY for C-a sources alone.

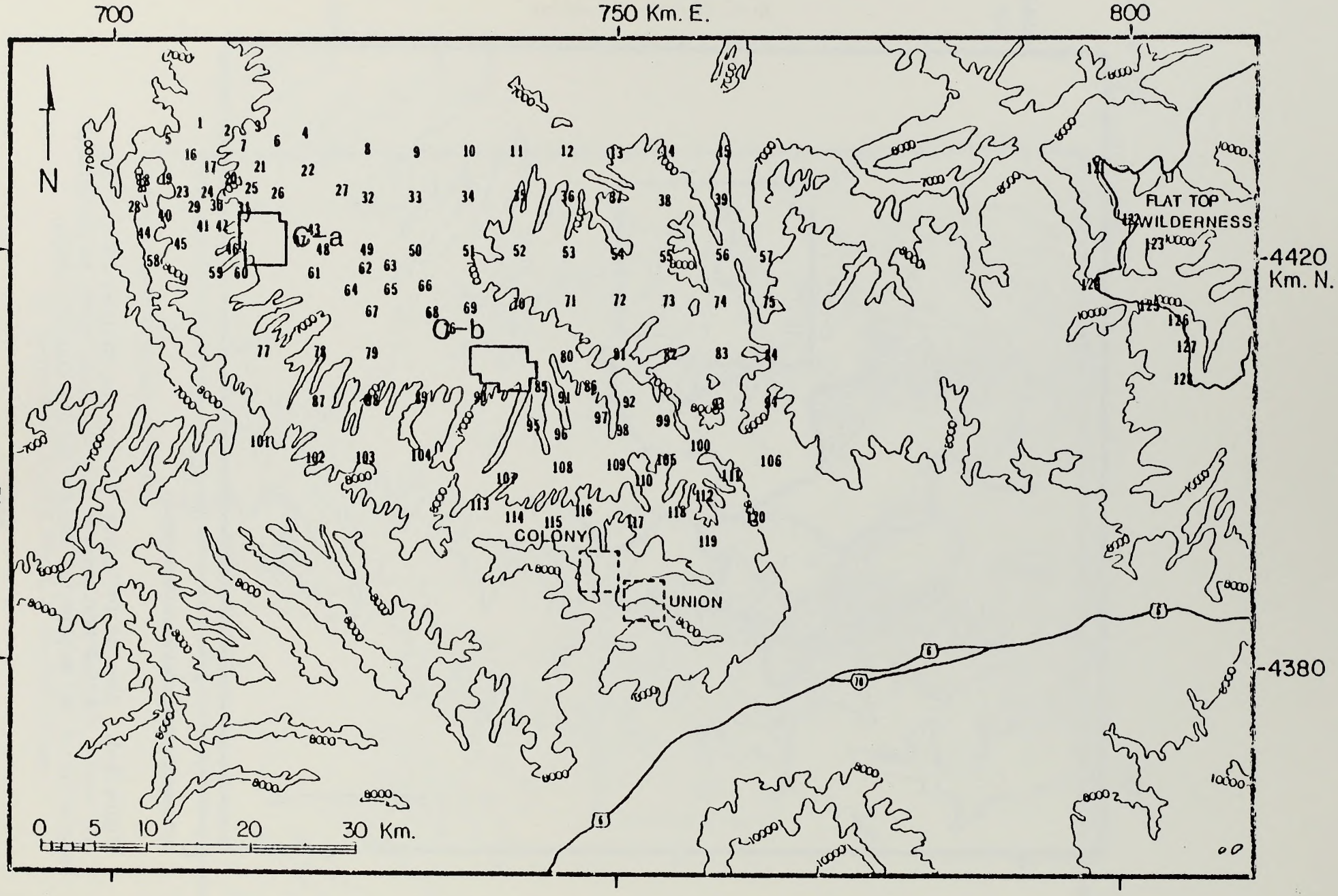


Figure 5-5 Approximate Receptor Layout for the MPSDM Modeling.

TABLE 5-3

A SUMMARY OF THE MAXIMUM SO_2 CONCENTRATIONS IN CLASS II AREAS AS CALCULATED BY MPSDM

	Maximum SO_2 Concentration Value ($\mu g/m^3$)	Receptor	Second Maximum SO_2 Concentration Value ($\mu g/m^3$)	Receptor	Class II PSD Increment ($\mu g/m^3$)
Tract C-a Sources Alone					
3-hour	20.7	1	20.3	2	512
24-hour	6.5	58	6.4	60	91
annual	0.7	21	0.4	22	20
All Sources					
3-hour	83.5	114	79.8	116	512
24-hour	21.8	109	19.8	114	91
annual	2.7	110	2.4	118	20

results for maximum 3-hour concentrations are somewhat different than those given by Sequential VALLEY (lower than Valley for C-a alone and higher for all sources). The maximum 3-hour concentrations for C-a sources did not result from low wind speed stable conditions, but rather from moderate to high wind speed neutral conditions. This is probably due to the less conservative treatment of low wind speed, stable flow to elevated terrain in the MPSDM model as compared to the Sequential VALLEY model (See Section 4.3.2). In addition the maximum 3-hour concentrations with all sources included do not resemble the maximum concentrations predicted from C-a sources alone, because the contribution from the other oil shale projects are much greater than the contribution from Tract C-a. Consequently, the maximum SO_2 concentrations are predicted to occur in the area around the other projects. An examination of the meteorological conditions for these periods shows that there is little or no contribution from the C-a sources to the combined maximums.

The maximum 24-hour value for Tract C-a sources alone was predicted for the meteorological conditions of March 3. This day was characterized by stable, low-wind speed conditions with easterly and northeasterly winds being predominant. This is consistent with the results of the Sequential VALLEY modeling which showed the location of the maximum concentration to be just west of Tract C-a on higher terrain. Thus, the conclusion based on data from the Sequential VALLEY modeling, that stable, low-wind speed flow results in the highest ground level concentrations, is reinforced by the 24-hour MPSDM results.

Annual-average concentrations were extremely low, and probably below detectability in all areas. The spatial distribution of the SO_2 emissions from Tract C-a alone for the three averaging periods is shown in Figures 5-6, 5-7, and 5-8. As previously described, the short-term maximum concentrations are shown as zones of influence, rather than isopleths.

When the SO_2 emissions for all permitted oil shale projects are included, the location of highest air quality impact changes significantly. The MPSDM modelling predicts that the highest concentrations occur to the southeast of Tract C-a, near the other oil shale developments. The isopleths and zones of influence indicate that the highest concentrations should occur

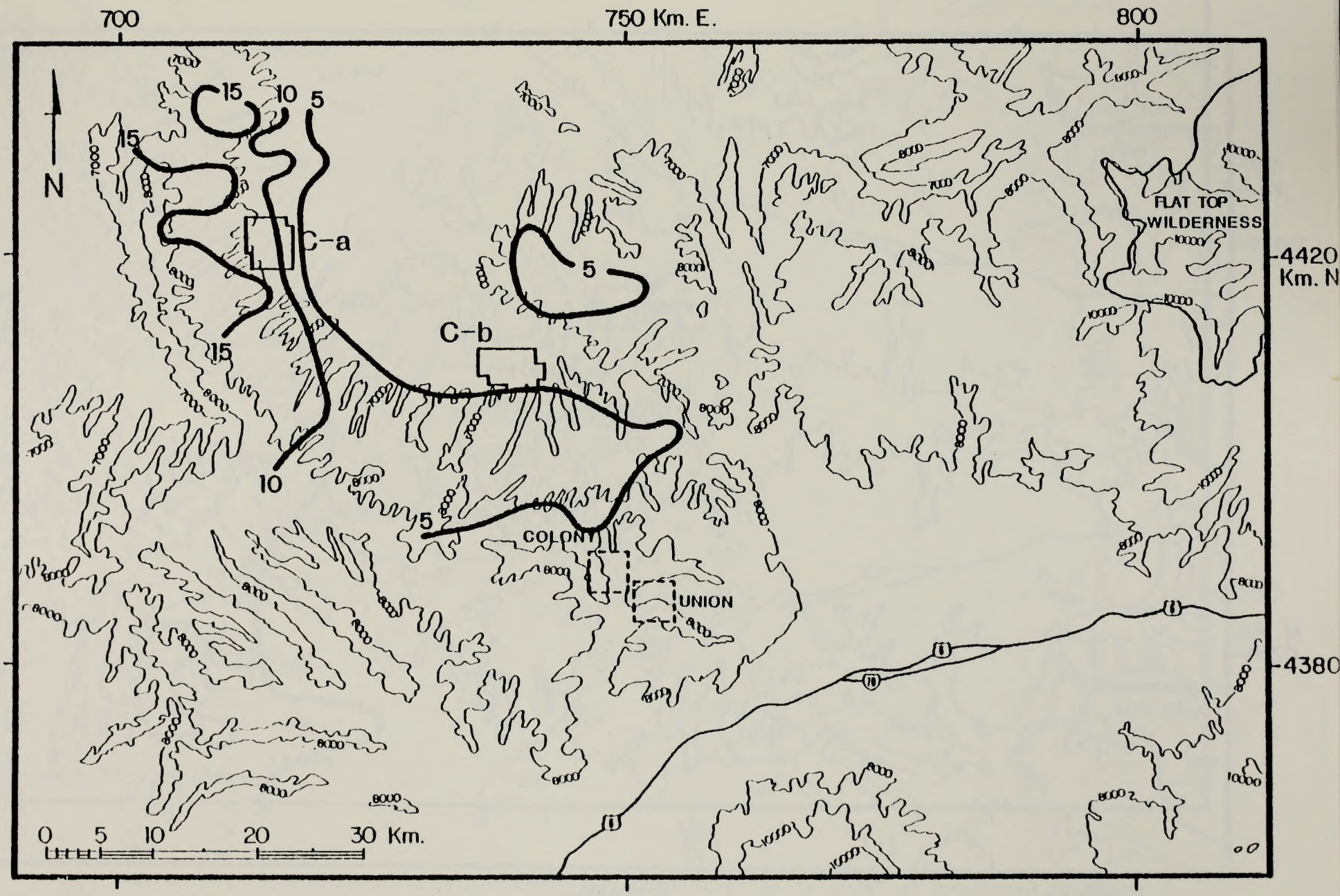


Figure 5-6. Zones of Influence showing the maximum 3-hour SO_2 concentrations in $\mu g/m^3$ at each point as calculated by MPSDM for C-a sources alone.

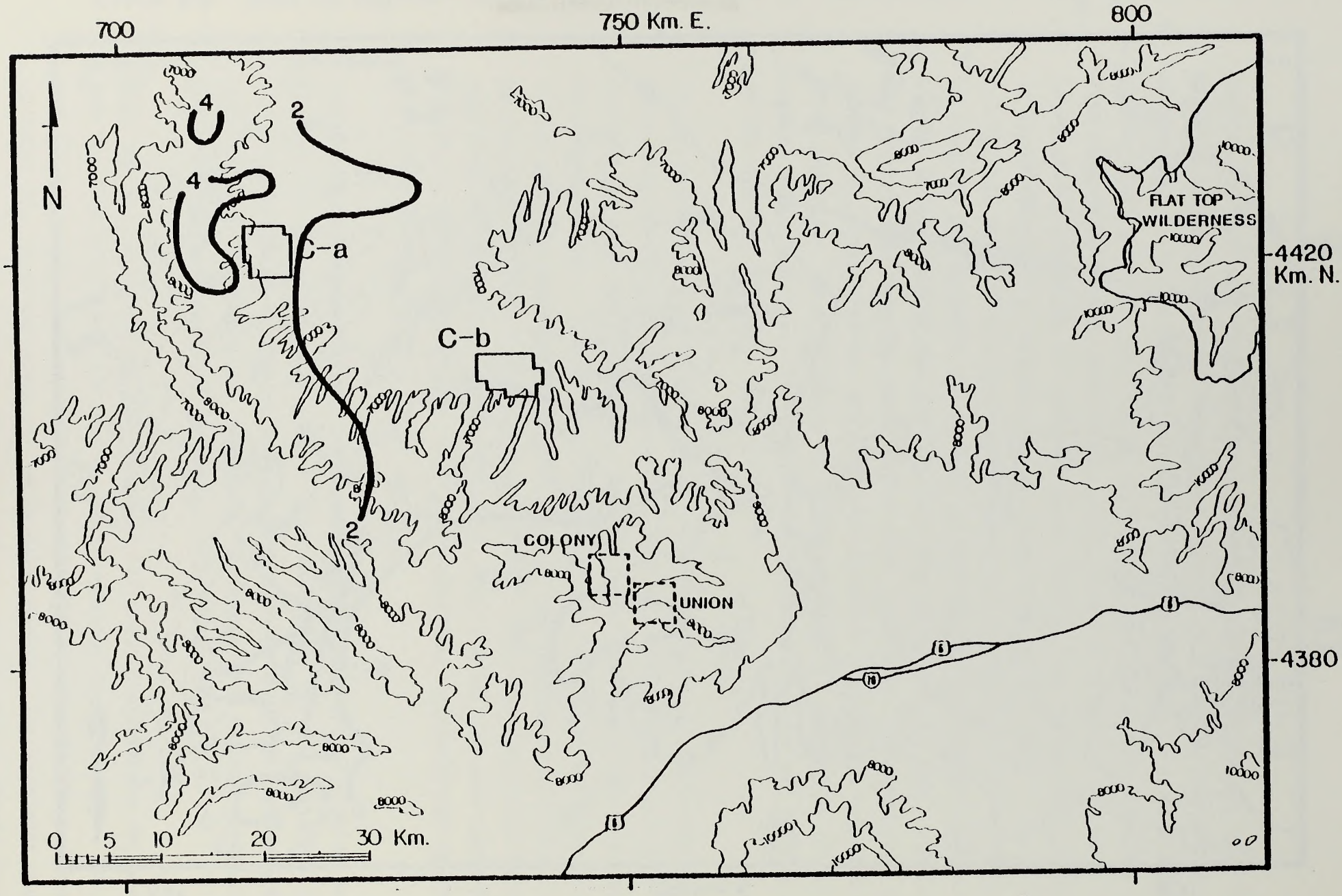


Figure 5-7. Zones of influence showing the maximum 24-hour SO_2 concentrations in $\mu g/m^3$ at each point as calculated by MPSDM for C-a sources alone.

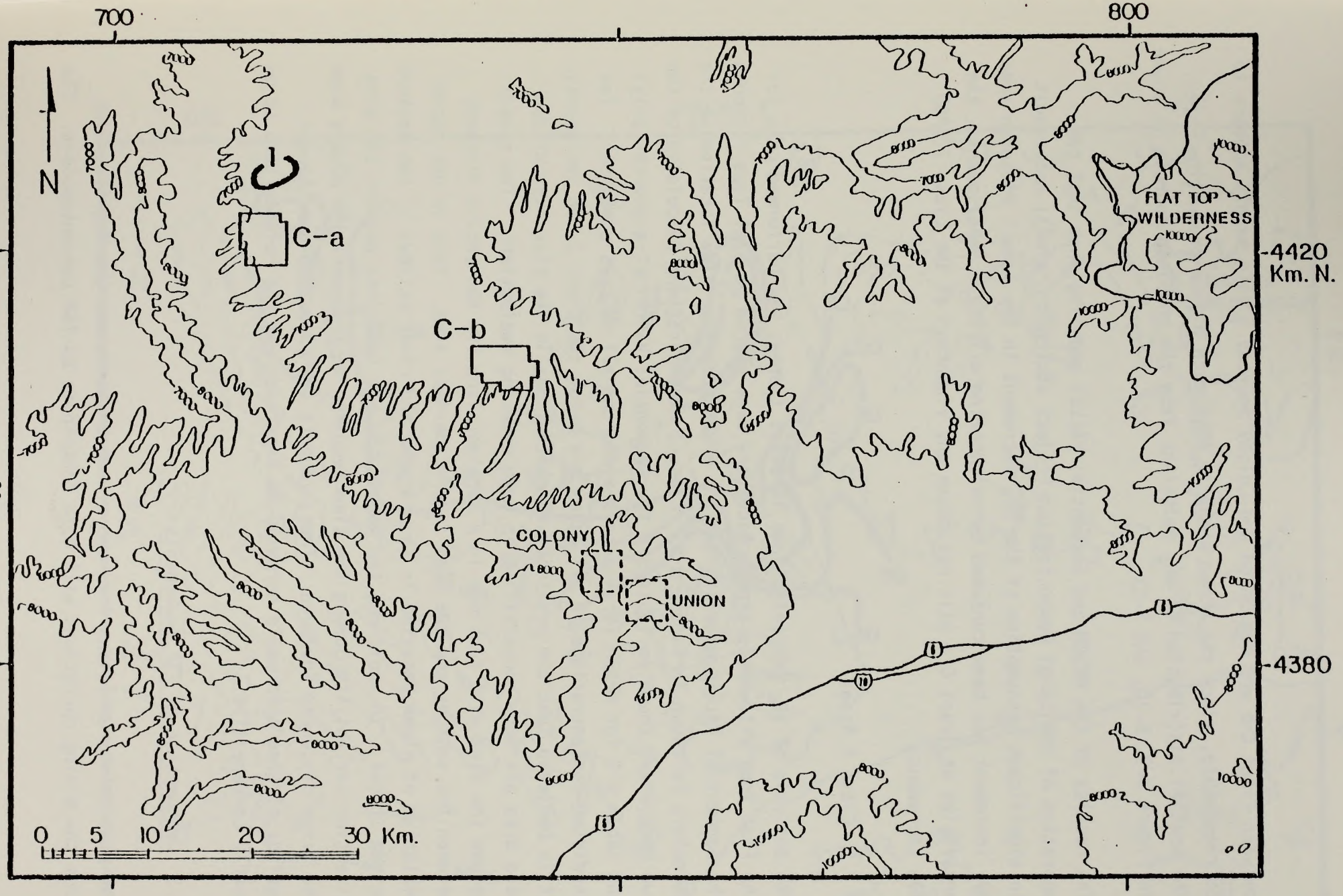


Figure 5-8. Isopleths of annual-average SO_2 concentration in $\mu g/m^3$ as predicted by MPSDM.

between Tract C-b and the Union and Colony sources. This result appears to be reasonable, since the other projects have much higher production rates. The spatial distribution of SO_2 emissions from the combined sources is shown in Figure 5-9, 5-10, and 5-11.

The results of the MPSDM and Sequential VALLEY modeling show that the operation of the Lurgi Demonstration Project at Tract C-a will not result in significant consumption of the SO_2 increment in the area. Although some SO_2 increment has been consumed by neighboring oil shale developments, the activities at Tract C-a will not cause any violation of the Class II PSD SO_2 increment.

5.1.2 Class I Areas

The analysis of SO_2 concentrations in Class I areas was performed only for the Flat Tops Wilderness area. Receptors were placed at Flat Tops for both the Sequential VALLEY modeling and the MPSDM modeling. The location of the receptors is shown in Figure 5-5. Class I concentrations calculated by the two models are shown in Table 5-4 for Sequential VALLEY (C-a sources only) and Table 5-5 for MPSDM (C-a sources alone and all sources combined). The predicted concentrations in all cases are below the Class I PSD increments. It is believed that the predicted concentrations in the Flat Tops Wilderness area are very conservative in both modeling evaluations. The models assume the wind will continue in a straight line for the entire distance between the sources and the Flat Tops Wilderness area. This is not representative of plume behavior in the canyons and river valleys of the western United States. In addition, the models, do not take into account the wind direction variability during the time required to transport the plumes over the large distances involved. Thus, impacts are predicted over longer periods of time than would normally be expected, and the results tend to be overly conservative.

5.2 Consumption of TSP Increments

The particulate emissions from the elevated stacks and the fugitive dust from the mining operations will both contribute to TSP concentrations. The

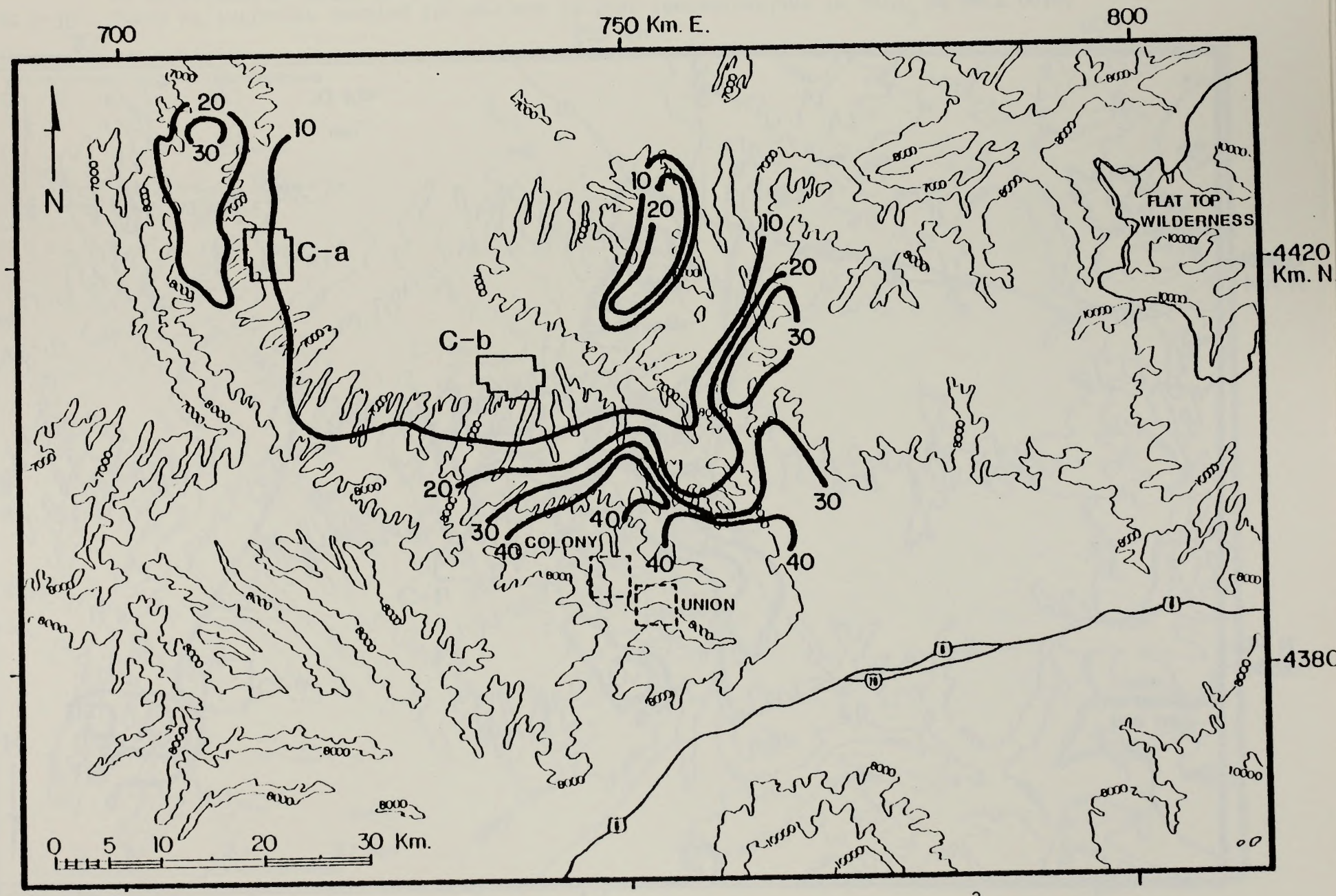


Figure 5-9. Zones of influence showing the maximum 3-hour concentrations in $\mu g/m^3$ at each point as calculated by MPSDM for all sources.

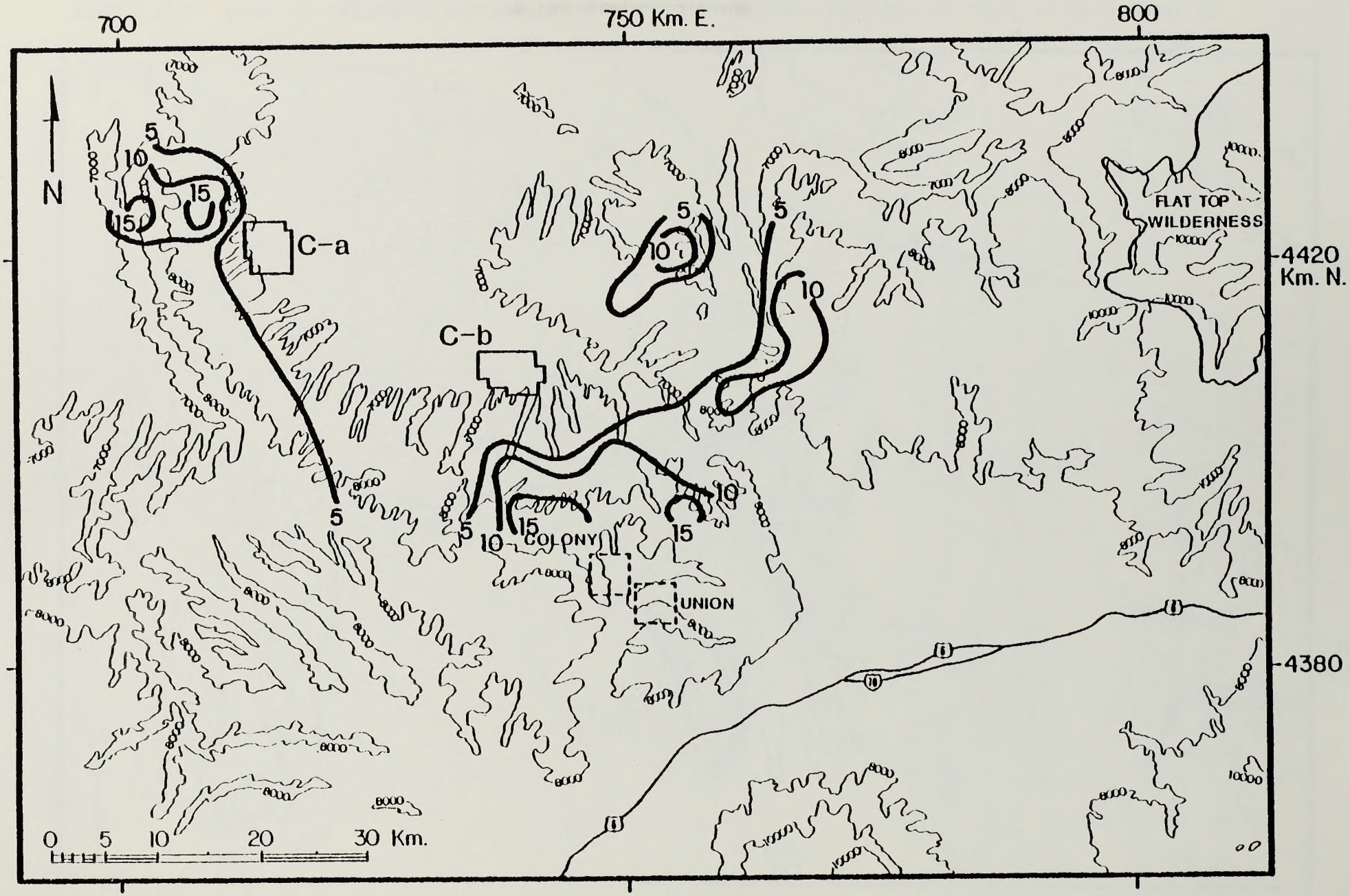


Figure 5-10. Zones of influence showing the maximum 24-hour concentrations in $\mu g/m^3$ at each point as calculated by MPSDM for all sources.

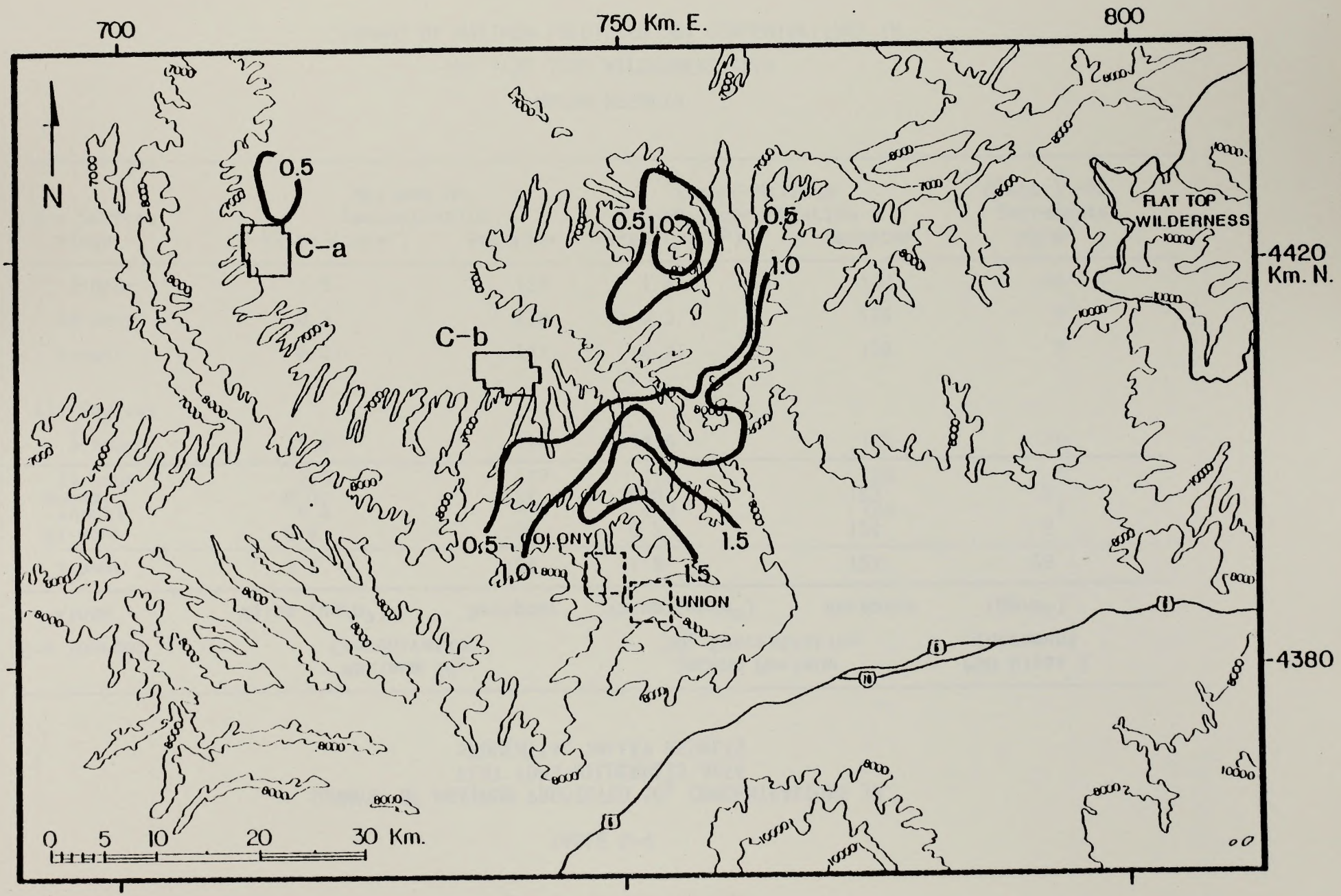


Figure 5-11. Isopleths of annual-average SO_2 concentration in $\mu g/m^3$ as calculated by MPSDM for all sources.

TABLE 5-4

SUMMARY OF MAXIMUM PREDICTED SO_2 CONCENTRATIONS IN
FLAT TOPS WILDERNESS AREA
SEQUENTIAL VALLEY RESULTS

C-a Sources	Maximum SO_2 Concentration		Second Maximum SO_2 Concentration		PSD Class I Increment
Alone	Value ($\mu g/m^3$)	Receptor	Value ($\mu g/m^3$)	Receptor	($\mu g/m^3$)
3-hour	2.2	124	1.2	123	25
24-hour	0.4	124	0.2	124	5
annual	0.01	124	0.01	123	2

TABLE 5-5

SUMMARY OF MAXIMUM PREDICTED SO_2 CONCENTRATIONS IN THE FLAT TOPS WILDERNESS AREA

MPSDM RESULTS

C-a Sources Alone	Maximum SO_2 Concentration Value ($\mu g/m^3$)	Receptor	Second Maximum SO_2 Concentration Value ($\mu g/m^3$)	Receptor	Class I PSD Increments $\mu g/m^3$
3-hour	1.9	124	1.8	122	25
24-hour	0.3	128	0.3	124	5
annual	0.01	121	0.01	124	2
All Sources					
3-hour	15.6	124	14.6	125	25
24-hour	2.6	127	2.5	128	5
annual	0.4	121	0.3	124	2

ground-level nature of the fugitive dust emissions, combined with the larger overall emission rates as compared to stack sources, makes the mine emissions more critical than stack emissions in terms of local Class II area PSD increment consumption. Conversely, the emissions from elevated stacks will likely be more significant than mine emissions in more remote areas such as the Flat Tops Wilderness area. An analysis of the fugitive dust emissions showed that peak emissions will occur in 1983 when Phase I processing and ore production and Phase II overburden removal is underway. Stack particulate will also be emitted during 1983.

5.2.1 Class II Areas

Maximum particulate concentrations were analyzed using the ERT MINE model and the EPA model PTMTP. Fugitive dust emissions were divided into 25 individual sources for input into the MINE model, including point sources, area sources, and line sources. Short-term emission rates for 1983 operations, and annual-average emission rates reflective of average 1983 activity were modelled. Maximum particulate emission rates from the Lurgi and MIS stacks were modeled with the PTMTP model.

Receptors were selected for the MINE modeling outside of the property boundary area for the Lurgi Demonstration Project (Figure 5-12). For those receptors and associated meteorological conditions where the highest TSP concentrations resulted from fugitive dust emissions, PTMTP runs were made with the same receptors and meteorlogical data. The concentrations of TSP from the PTMTP runs were negligable compared to the TSP concentrations from fugitive sources.

The highest and second highest TSP concentrations outside the property boundaries (Figure 5-13) are shown in Table 5-6. These concentrations are well below the allowable PSD increments.

The predicted maximum 24-hour average concentration in 1983 occurred at the northern tract boundary directly north of the open pit. Figure 5-13 shows the location of the peak value. Also shown in Figure 5-13 are zones of influence for the maximum 24-hour TSP concentrations in 1983. The maximum

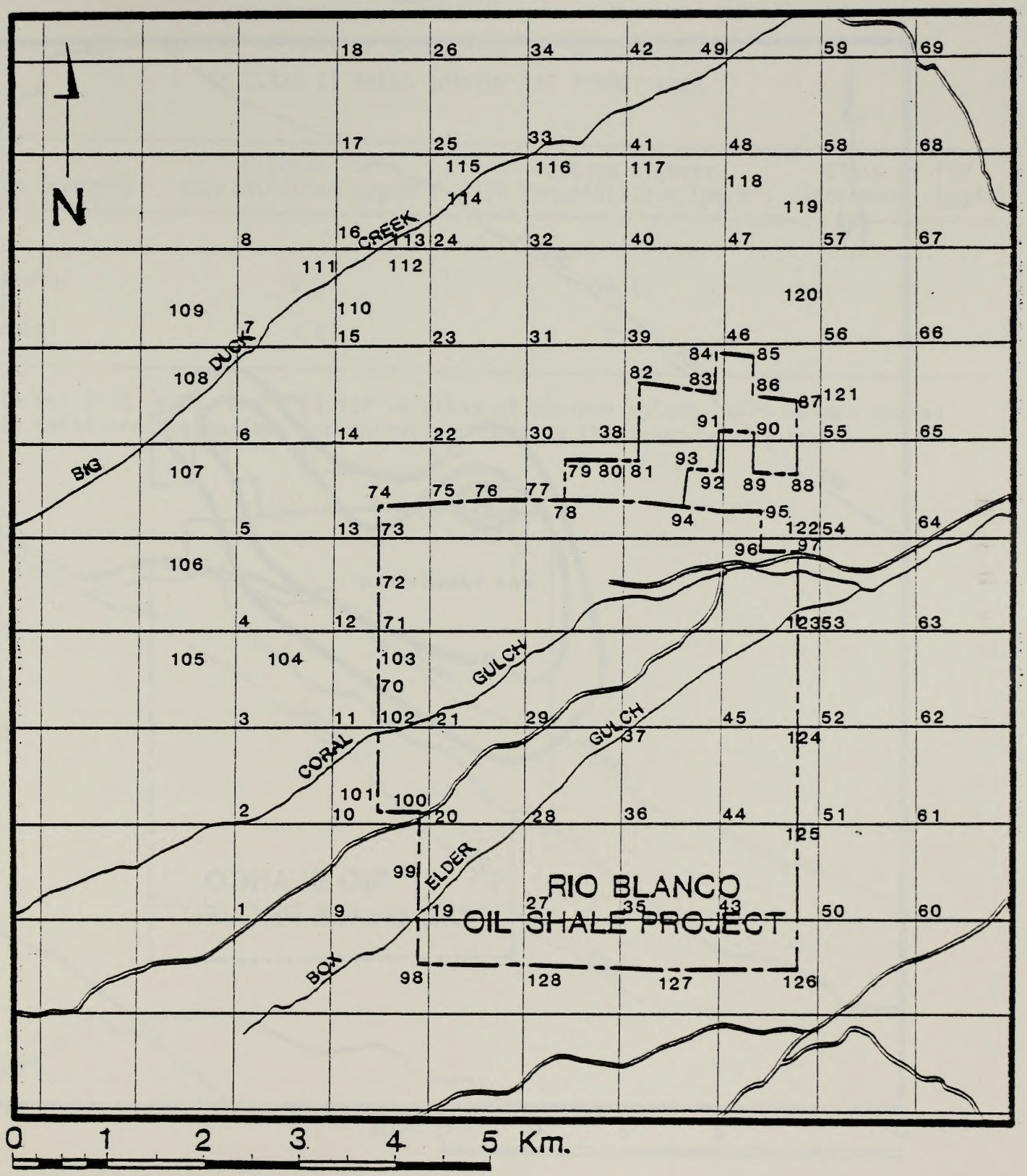


Figure 5-12. Receptor locations for the MINE modeling of TSP.

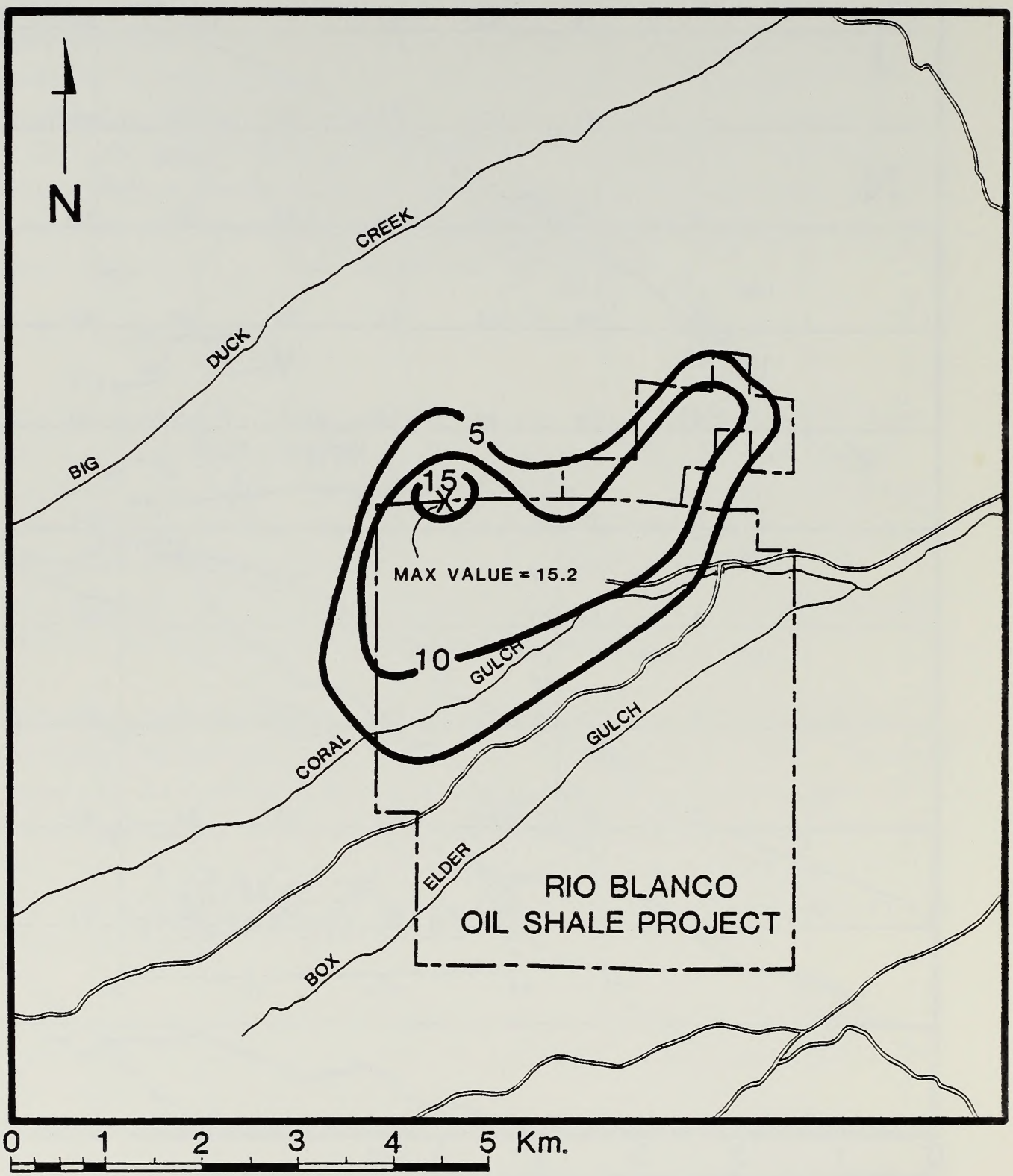


Figure 5-13. Zones of influence showing maximum 24-hour TSP concentrations in $\mu g/m^3$ as calculated by MINE for the PSD increment consuming emissions during 1983.

TABLE 5-6

SUMMARY OF MAXIMUM CALCULATED TSP CONCENTRATIONS
IN CLASS II AREAS OUTSIDE THE PERMIT AREA

Emission Scenario	Highest TSP[1] Concentration ($\mu g/m^3$)	Second Highest TSP Concentration ($\mu g/m^3$)	Class II TSP Increment, ($\mu g/m^3$)
1983:			
24-hour	15.2	14.4	37
annual	3.5	2.7	19

[1]See Figures 4-12, 4-13, and 4-14 for location of maximum values. The values quoted in this table are the maximum concentrations outside the tract boundaries.

values occurred during stable flows with winds from the south. Figure 5-14 shows the isopleths of annual-average concentration for 1983. Peak annual average concentrations are expected to occur on the eastern boundary of the tract. This is consistent with the predominant winds (west-southwest) at Tract C-a.

The short-term and annual concentrations during 1981, 1982 and 1984 are expected to be lower in magnitude than those for 1983, due to the lower emission rates during these periods.

It should be noted that once overburden has been removed, pit activities such as drilling, blasting, and ore removal will be below grade. It is anticipated that the fugitive dust generated from these below grade operations will tend to impact the pit walls to some degree and therefore not disperse to areas outside the pit. All fugitive dust was modeled as being emitted from ground level and not below grade. Therefore, the ambient concentrations of TSP due to operations that include below grade mining are probably conservative. In addition, several of the operations modeled as surface emissions actually have release points located some distance above the ground, including the centralized baghouse of the crushing and grinding building and the various storage piles (topsoil, overburden, and shale ore). The added dilution that occurs before the plumes from these sources impact the ground also serves as a conservative factor in modeling these emissions.

There could be some additional contributions to the TSP concentrations in the project area from the other oil shale developments. These would not, however, impact the project area during the stable flows which are expected to produce the maximum concentrations from the Lurgi Demonstration Project mining sources. The results of the elevated stack modeling for SO_2 showed that impact of the other sources (C-b, Colony, Union) in the immediate area around Tract C-a is expected to be minimal. Thus, it is believed that the impacts on the project area of the TSP emissions from these sources can be ignored.

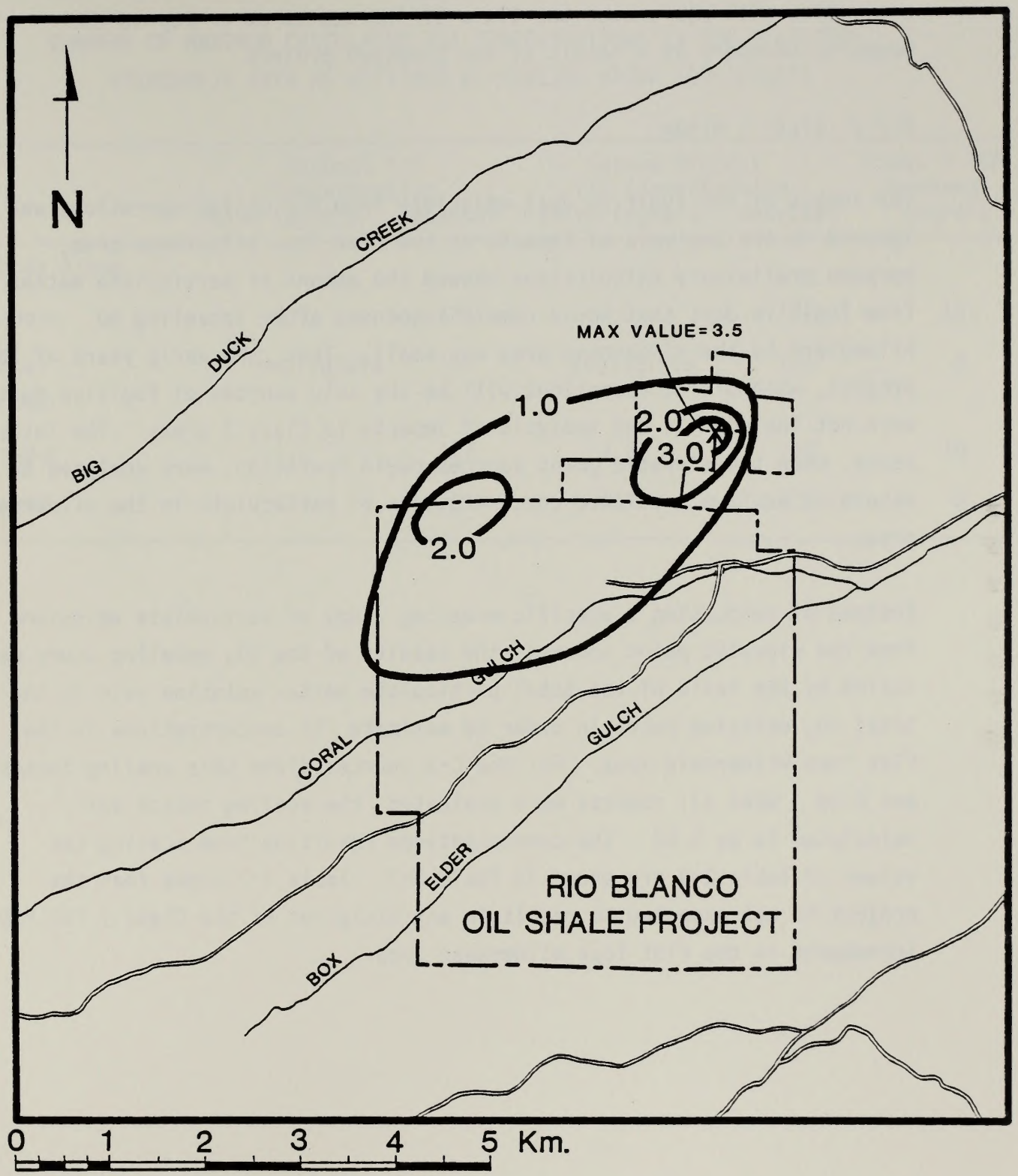


Figure 5-14. Isopleths of annual-average TSP concentration in $\mu g/m^3$ as calculated by MINE for the PSD increment consuming emissions during 1983.

The conclusion is, then, that TSP concentrations from all operational activities will not exceed the Class II increments at or beyond the property boundary as a result of the proposed project.

5.2.2 Class I Areas

The impact of the fugitive dust emissions from the mining operations was ignored in the analysis of impacts on the Flat Tops Wilderness area, because preliminary calculations showed the amount of particulate matter from fugitive dust that would remain suspended after traveling 80 kilometers to the wilderness area was small. Thus, the early years of the project, when mining operations will be the only sources of fugitive dust, were not included in the analysis of impacts to Class I areas. The later years, when the elevated point sources begin operation, were analyzed to determine maximum predicted concentrations of particulate in the wilderness area.

Instead of conducting a specific modeling study of particulate emissions from the elevated point sources, the results of the SO_2 modeling study were scaled by the ratio of the total particulate matter emission rate to the total SO_2 emission rate, in order to estimate TSP concentrations in the Flat Tops Wilderness area. For the C-a sources alone this scaling factor was 0.48. When all sources were evaluated, the scaling factor was calculated to be 0.63. The concentrations resulting from scaling the values of Table 5-5 are shown in Table 5-7. Table 5-7 shows that the project is not expected to result in any violation of the Class I TSP PSD increments in the Flat Tops Wilderness area.

TABLE 5-7

SUMMARY OF MAXIMUM CALCULATED TSP CONCENTRATIONS IN THE FLAT TOPS WILDERNESS AREA AS OBTAINED BY SCALING MPSDM SO^2 RESULTS

	Highest TSP Concentration		Second Highest TSP Concentration		Class I TSP Increment
	Value ($\mu g/m^3$)	Receptor	Value ($\mu g/m^3$)	Receptor	($\mu g/m^3$)
C-a Sources Alone					
24-hour	0.1	128	0.1	124	10
annual	negligible	121	negligible	124	5
All Sources					
24-hour	1.6	127	1.6	128	10
annual	0.3	121	0.2	124	5

Sec. 6.0

6.0 COMPLIANCE WITH STATE AND FEDERAL AMBIENT STANDARDS

Compliance with Colorado and National Ambient Air Quality Standards (CAAQS and NAAQS, respectively) is determined by adding the existing background concentrations to the additional pollutant loadings resulting from the various permitted sources in the Piceance Basin area. The following discussions address the determination of background air quality at Tract C-a, and the predicted compliance with the CAAQS and NAAQS.

6.1 Determination of Background Concentrations

RBOSC has been gathering air quality data in the vicinity of Tract C-a since February 1975. The objective of this monitoring effort has been to determine background concentrations prior to major development on Tract C-a. Air quality parameters measured continuously include sulfur dioxide (SO_2), oxides of nitrogen (NO_x), nitric oxide (NO), carbon monoxide (CO), and ozone (O_3). Total and non-methane hydrocarbons (THC and NMHC respectively) were measured continuously from February 1975 to February 1978. Total Suspended Particulate (TSP) has been measured about every fourth day from February 1975 through November 1978 and every third day from December 1978 to the present. The number of locations of simultaneously operating monitoring stations has varied from one to four depending on the time period and pollutant (see Section 9, Chapters 2 and 3 of the Development Plan).

The following discussions address 1) the completeness of the data base, 2) the validity of the data, and 3) concentrations above instrument threshold. The last section lists representative background air quality concentrations that can be added to the maximum predicted increase in concentrations due to the Lurgi Demonstration Project to determine compliance with the applicable State and Federal ambient air quality standards.

6.1.1 Data Completeness

RBOSC has reported measurements from continuous air quality monitoring stations from February 1975 through November 1979. This constitutes a 4.8-year data base for parameters including SO_2, NO_x, NO, CO, and O_3.

TSP measurements have been reported for the same period in accordance with Colorado Department of Health requirements. Continuous THC and NMHC measurements were obtained for the first three years of monitoring.

The period of sampling and the frequency of sampling constitutes an extensive data base for determining background concentrations prior to major development on the tract. This data base of nearly 5 years should be adequate to evaluate variations from year to year in a remote area.

6.1.2 Data Validity

The degree of validity of a given data set can be judged by internal and external quality assurance checks. Internal quality assurance checks include regular instrument calibration with concentrations traceable to the National Bureau of Standards, regular station visits to identify and correct instrument problems, third party audits of the entire data collection and reduction program, and other quality assurance/quality control (QA/QC) procedures. External quality assurance checks include comparing summaries of the data of interest to summaries of the same parameters at another nearby location. When both sets of data are affected by similar pollutant sources and meteorological conditions, long term averages at both locations should be similar.

6.1.2.1 Internal Consistency Checks. RBOSC has instituted comprehensive QA/QC procedures to insure the reliability of the data. This program includes 1) an automatic data acquisition system with strip chart backup located on the tract, 2) documentation by the site technician of all calibrations and system malfunctions, 3) weekly zero and span calibrations of the air quality instrumentation, 4) utilization of control charts onsite to detect drifting in the weekly data, 5) quarterly calibrations of the air quality instrumentation by both the internal technical staff and an independent auditing team, and 6) review of the analog and digital data by qualified analysts.

The air quality instruments are calibrated using pollutant sources traceable to National Bureau of Standards (NBS) standards. The carbon monoxide and oxides of nitrogen analyzers are calibrated using a known concentration of test gases which have been certified by the vendor.

Calibration of the sulfur dioxide instrument is conducted with a permeation tube source using a Monitor Labs calibrator. The ozone analyzer is calibrated using the gas phase titration method.

Each instrument is tested at least once a week by inserting a zero pollutant concentration and at least one known span concentration. These tests provide data on instrument drift and insure that the instrument will respond to a measurable level of pollutant concentration in the ambient air.

The quarterly field calibrations are used to determine the accuracy of the data recorded by the instruments. No correction factors are normally required to adjust the data. Independent quarterly audits by an EPA contractor (Rockwell International) are used to check the internal calibration methods. Almost all of the readings for audited instruments have been within ±10 percent of the readings for the auditor's equipment, which conforms with EPA guidelines (RBOSC 1980).

6.1.2.2 External Consistency Checks. Tract C-b is located about 20 Km from Tract C-a and is in the same airshed in the Piceance Basin. Because there are few significant anthropogenic pollutant sources in the Piceance Basin and because both tracts are affected by similar local scale, mesoscale, and synoptic weather conditions, long-term background concentrations measured at C-a should be similar to long-term concentrations measured at C-b.

Table 6-1 is a summary of reported annual averages of the various measured pollutants at both tracts. The values from the two lease tracts are similar. This supports the validity of the Tract C-a data.

TABLE 6-1

REPORTED ANNUAL AVERAGES OF MEASURED POLLUTANTS, TRACTS C-a AND C-b

Parameter	Annual Averages, ppb	
	C-a	C-b[2]
SO_2	10[1]	0.3-0.5
NO_x	5-9	3-16
NO_2	1-7	1-4
O_3	31-57	35
CO	500-600	597-1,180
THC	not reported	1,264-2,080
NMHC	not reported	55-425
TSP (geometric mean, $\mu g/m^3$)	9-26	6-11

1 The measured annual averages of SO_2 at C-a were below the "reliable threshold of detection" of the analyzer (20 ppb). As per EPA's Quality Assurance Handbook (EPA 1977), RBOSC generally chose to report values equal to one-half the threshold value.

2 Occidental and Ashland Oil 1976, 1977a, 1977b, 1978, and 1979.

6.1.3 Concentrations Above Threshold

Table 6-2 shows the reported maximum measured concentrations for the C-a ambient air monitoring Sites 1, 2, and 3 from February 1975 through November 1979.

6.1.3.1 SO_2. SO_2 concentrations have rarely been above threshold. Short term excursions above threshold could have been caused by sources of H_2S which oxidized to SO_2 prior to reaching the C-a SO_2 monitors.

C-a monitoring site 3 is located near a creek that receives discharges from groundwater sources. Water from this source contains reduced sulfur compounds which are probably released to the atmosphere during the discharge of the water to the surface (RBOSC 1978, 1980). There are also natural gas production facilities in the Piceance Basin that probably generate fugitive emissions of H_2S and other reduced sulfur compounds.

6.1.3.2 NO/NO_x. NO/NO_x concentrations are rarely above threshold. Short-term excursions of NO_x above threshold probably result from miscellaneous vehicle exhaust in the area.

6.1.3.3 CO. The reliable threshold of detection of the CO analyzer is 1 ppm. Only rarely have CO concentrations exceeded this value. Excursions of CO above 1 ppm have probably been caused by instrument drift and/or vehicle exhaust in the area.

6.1.3.4 O_3. 03 concentration measurements are actually representative of total oxidants in the ambient air. O_3 concentrations are usually above instrument threshold and exhibit diurnal and seasonal fluctuations. Such readings are consistent with values measured elsewhere in the area. Maximums tend to occur in the daytime and in the summer. Relatively high O_3 concentrations at Tract C-a may be caused by a number of factors including (1) growth of the convective boundary layer, (2) stratospheric injection, (3) long-range transport, or (4) photochemical reactions. It is impossible, however, to specify the specific origin of background O_3 in the area. O_3 is not considered a significant issue for this project since the

TABLE 6-2

MAXIMUM MEASURED CONCENTRATIONS AT TRACT C-a

(All values in ppb except TSP which are $\mu g/m^3$)

Parameter		2/75-1/77 Site 1	2	3	12/77-11/78 Site 1	2	3	12/78-11/79 Site 1	2	3
SO_2	1 hr	90		50	30		110	10		90
	3 hr	43	67	19						
	24 hr	14	9	7						
	annual	3	2	1	10		10	10		10
NO_x:	1 hr	234		154	23			48		
	24 hr									
	annual	9		6	6			5		
TSP:	24 hr	211	102	247	59	60	160	303	87	192
	ann. geom. mean	9	9	21	14	13	26	11	12	21
O_3:	1 hr	68		89	88		72	80		76
	annual	34		31	57		38	49		38
CO:	1 hr	4,200		6,000	500			1,500		
	8 hr	3,585		4,418						
	annual	600		600	500			500		
NMHC:	3 hr	303	289	135						
	annual				- not reported -					

anticipated hydrocarbon emissions are very low. Thus, the discussion of O_3 in this report has been confined to a presentation of the measured data.

6.1.3.5 TSP. Short-term TSP concentrations are generally representative of a rural semi-arid area where sparse vegetation and dry loose topsoil are conducive to the mechanical entrainment of dust during medium to strong wind conditions. The highest TSP values recorded at C-a have been caused by particulates generated from earth moving and related activities during the construction phase of the experimental Modified In-Situ retorts.

6.1.3.6 THC/NMHC. THC and NMHC were measured during the first three years of monitoring at C-a. With the consent of the Area Oil Shale Office, monitoring of these parameters was subsequently discontinued because the available techniques are inadequate for measuring the relatively low concentrations of NMHC found at Tract C-a.

6.1.4 Derived Background Air Quality Concentrations

Average annual concentrations at Tract C-a have varied from year to year and location to location. The median of all these reported annual averages can be taken, however, as a reasonable approximation of background concentration for each air quality parameter. Based upon the annual concentrations listed in Table 6-2, median values, by parameter, are as follows:

SO_2	10 ppb
NO_x	6 ppb
TSP	13 $\mu g/m^3$
O_3	38 ppb
CO	550 ppb
NMHC	unknown

Dispersion models predict concentrations in $\mu g/m^3$. National Ambient Air Quality Standards are defined in $\mu g/m^3$ at sea level pressure. Therefore, the measured background concentrations listed above should be converted to $\mu g/m^3$ (except for TSP which is already expressed in those units) at sea

level pressure prior to comparisons with sea level standards. This conversions can be done with the following formula:

$$\mu g/m^3 = ppb \times \frac{\text{mol. wt. of gas}}{22.414} \times \frac{273^\circ K}{\text{C-a Temp. } (^\circ K)} \times \frac{\text{C-a Pressure (mm Hg)}}{760 \text{ mm Hg}}$$

Assuming that average annual temperature and pressure conditions at Tract C-a are 279°K and 590 mm Hg respectively, the background concentrations are as follows:

SO_2	- 22 $\mu g/m^3$	O_3	- 62 $\mu g/m^3$
NO_x	- 9 $\mu g/m^3$	CO	- 520 $\mu g/m^3$
TSP	- 13 $\mu g/m^3$		

6.2 Combined Impacts of Project Plus Background

The proposed project must demonstrate compliance with all ambient air quality standards in effect for the project area. Table 6-3 shows the National Ambient Air Quality Standard (NAAQS) and Colorado Ambient Air Quality Standards (CAAQS) applicable to the Tract C-a sources.

Although construction-related emissions can be excluded from the fugitive emission inventory when determining PSD increment consumption, these emissions must be included when comparing Federal and State air quality standards to ambient TSP concentrations. For purposes of PSD increment consumption, 1983 activities generated the highest emission rates; however, when construction-related emissions are included, 1981 activities produced the highest shortterm emissions and 1982 activities generated the highest annual emissions. Thus, annual and 24-hour ambient TSP concentrations were estimated by adding the model predictions for 1982 and 1981 respectively, to the background TSP concentrations to determine compliance with NAAQS and CAAQS.

In this study air quality modeling has been performed only for SO_2 emissions from the various stacks. By scaling the SO_2 concentrations using

TABLE 6-3

AMBIENT AIR QUALITY STANDARDS ($\mu g/m^3$)

Pollutant	Averaging Time	Federal NAAQS	CAAQS
Sulfur dioxide	annual	80	N/A
	24-hour	365	N/A
	3-hour	1300[1]	N/A
Total Suspended Particulates			
	annual[2]	75(60[1])	75(60[1])
	24-hour	260(150[1])	260(150[1])
Nitrogen Dioxide	annual	100	100
Carbon Monoxide	1-hour	40,000	40,000
	8-hour	10,000	10,000
Photochemical Oxidants			
	1-hour	235	235

[1] Denotes secondary standard

[2] Geometric mean

the emission rates from the various sources, however, an estimate for the appropriate averaging time for each pollutant can be obtained. The results of this scaling are shown in Table 6-4.

The model results were then added to the background values presented in the previous section. The results are shown in Table 6-5 and indicate that no ambient air quality standards are predicted to be exceeded by the proposed project.

TABLE 6-4

SCALED CONCENTRATIONS FOR POLLUTANTS
NOT SPECIFICALLY MODELLED

Pollutant[1]	SO_2 Concentration Scaled	Scaling Factor	Scaled Concentration
C-a Sources Alone:			
Nitrogen Dioxide	0.7 (annual)	3.49	2.4 (annual)
Carbon Monoxide[2]	20.7 (3-hour)	0.54	11.2 (1-hour and 8-hour)
All Sources			
Nitrogen Dioxide	2.7 (annual)	4.84	13.1 (annual)
Carbon Monoxide[2]	83.7 (3-hour)	7.31	611.8 (1-hour and 8-hour)

[1] No analysis is presented for oxidant since there is no acceptable method for scaling hydrocarbon emissions to determine oxidant concentrations.

[2] One value was used here for both 8-hour and 1-hour carbon monoxide concentrations. The value scaled was the 3-hour SO_2 model prediction.

TABLE 6-5

CALCULATION OF EXPECTED TOTAL POLLUTANT CONCENTRATIONS OBTAINED BY SUMMING MODEL PREDICTIONS WITH BACKGROUND CONCENTRATIONS

(ALL VALUES IN $\mu g/m^3$)

Pollutant	Model Prediction (all Sources)	Background	Total
Sulfur dioxide			
3-hour	84	22	106
24-hour	22	22	44
annual	3	22	25
Total Suspended Particulates			
24-hour	97.7	13	110.7
annual	18.5	13	31.5
Nitrogen Dioxide			
annual	13	9	22
Carbon Monoxide			
1-hour	612	520	1,132
8-hour	612	520	1,132
Photochemical Oxidant (O_3)			
1-hour	1/	62	1/

1/ No analysis is presented for photochemical oxidant; however, the very low level of hydrocarbon emissions from the proposed project makes it very unlikely that any significant impact or oxidant concentration would occur.

Sec. 7.0

7.0 IMPACTS TO AIR QUALITY RELATED VALUES

Visibility, soils, and vegetation impacts resulting from the air pollutant emissions of the proposed Lurgi Demonstration Project and other regional sources are discussed below.

7.1 Impacts to Visibility

7.1.1 Flat Tops Wilderness Area

As discussed in Chapter 4, draft EPA guidelines for estimating visibility impairment (EPA 1980) were used in the estimation of impacts on the Flat Tops Wilderness. The screening procedures outlined in the May 30, 1980 document issued by EPA specified five critical parameters to determine if the potential exists for visibility impact on a Class I area such as the Flat Tops Wilderness. These parameters are as follows:

- The minimum distance from the project to the Class I area
- The geographic location of both the project and the Class I area
- The particulate emission rate
- The SO_2 emission rate
- The emission rate of nitrogen oxides (NO_x)

In this analysis, a value of 81 kilometers was used as the minimum distance between Tract C-a and the Flat Tops Wilderness area. The geographic location of the emission source and this Class I area were used to determine the background visual range, using a map contained in the EPA document. For this analysis both the emission source and the Flat Tops Wilderness Area were assumed to be within the region assigned the highest background visual range in the draft EPA document (170 kilometers). The guideline procedure (EPA 1980) was followed which resulted in the calculation of three criteria parameters. If the absolute value of each is less than 0.1,

the EPA document states that the project can be assumed to have little or no impact on visibility in the Class I area.

For the Lurgi Demonstration Project the absolute values calculated for the three parameters, called C1, C2 and C3, were 0.01, 0.01 and 0.002 respectively. Thus, the proposed development can be assumed to have little or no impact on visibility in the Flat Tops Wilderness. Assumptions and calculations used in estimating the visibility impacts are included in Appendix D.

7.2.1 Area in the Vicinity of Tract C-a

The particulate concentrations resulting from the mining operations will result in some very localized dust plumes in the immediate area surrounding the mine. These would only be visible occasionally and should not result in any regional visibility degradation. The gaseous emissions from the Lurgi Demonstration Project should not have any effect on visibility in the vicinity of Tract C-a.

7.2 Impacts to Soils and Vegetation in the Flat Tops Wilderness Area and in the Vicinity of Tract C-a

The Lurgi Demonstration Project will be a source of sulfur dioxide (SO_2), oxides of nitrogen (NO_x) and particulate (TSP) emissions. For the purposes of this analysis, the maximum allowable incremental limits for SO_2 and TSP for PSD Class II areas were assumed to represent the maximum concentrations of pollutants which the sites will receive due to emissions from C-a singly or in combination with other PSD increment-consuming sources. Thus, the Class II increments are the concentrations used in this impact assessment.

7.2.1 Particulate

Particulates may include a wide range of particle sizes, forms, and chemical compositions. Each of these factors affects the potential environmental impact of the particulates which are emitted. Particulates which are deposited on plant surfaces can remain as a dry dust, can be removed by wind or rain, or can form a hard encrustation. The primary effects of

particulate on vegetation include inhibiting gas exchange, increasing leaf temperature, and reducing photosynthesis. Particulate deposits may be directly toxic to vegetation if they contain soluble toxic elements which can be hydrated and taken up through leaf surfaces.

The soil forms the ultimate sink for particulates. Again, the chemical and physical characteristics of the particulates determine the nature of the impacts produced in the soil environment. Litter decomposition, mineralization, and nutrient cycling may all potentially be affected by particulate deposition. The deposition of soluble toxic elements can be harmful to plants if they are taken up through the roots.

Particulates, however, are generally not considered to be pollutants which produce significant environmental impacts on soils and vegetation. Literature data which assess the impacts of particulates on vegetation are quite limited. Generalized impact assessments for particulate are difficult to conduct since the chemical composition, deposition rate, and solubility of potentially toxic elements must be known in order to evaluate the potential impact of these emissions.

Particulate deposition on vegetation should result in only a superficial coating which is subject to removal by wind and rain. Since available data at this time do not indicate that particulate emissions will be of environmental concern, they were not assessed in further detail.

7.2.2 Oxides of Nitrogen

The two most important NO_x pollutants are nitric oxide (NO) and nitrogen dioxide (NO_2). Plant injury is thought to be primarily a function of exposure to NO_2. The combustion of fossil fuels and industrial processes are two important anthropogenic sources of NO_x.

The potential for NO_2 impacts to vegetation is a function of the pollutant dose, environmental conditions of exposure, plant species exposed, and the genetic and physiologic characteristics of the exposed plants (Middleton

et al. 1958). The modeling has shown no violations of the NO_2 NAAQS (0.05 ppm annual average). This standard is considered adequate to protect vegetation from injury (NAS 1977).

Attempts have been made in the past to evaluate the potential interaction of SO_2 and NO_2 and resultant vegetation injury. The results of these studies have been mixed and inconclusive. Although the effects produced by the combined pollutants have been generally more adverse than those of exposure to each pollutant alone, the occurrence and significance of these interactions under ambient conditions remains unresolved.

In summary, data available at this time do not indicate that NO_x emissions associated with the Lurgi Demonstration Project will significantly impact project area vegetation.

7.2.3 Sulfur Dioxide

7.2.3.1 The Impact of SO_2 on Vegetation in Tract C-a. The vegetation on or near Tract C-a can be divided into three major habitat types: pinyon-juniper, mixed brush, and sagebrush. Section 8, Chapter 2 of the Development Plan (RBOSC 1980) contains a detailed description of the vegetation of the project area.

Very little SO_2 research has been conducted with the plant species found near Tract C-a. Exposures of western wheatgrass (*Agropyron smithii*) at Colstrip, Montana to SO_2 concentrations averaging 0.073 ppm for the entire growing season did not produce foliar SO_2 injury, but did induce accelerated leaf senescence (Heitschmidt et al. 1978; Rice et al. 1979). Tingey et al. (1976) exposed western wheatgrass, Idaho fescue (*Fescua idahoensis*), prairie junegrass (*Koeleria cristata*), needle-and-thread grass (*Stipa comata*), and fringed sage wort (*Artemisia frigida*) to 0.5 to 2.0 ppm SO_2 for four hours. None of the plant species were injured at concentrations below 1.0 ppm for four hours. Existing concentrations at Tract C-a are quite low and the maximum allowable 3-hour incremental for SO_2, 0.2 ppm (512 $\mu g/m^3$), is considerably below both the acute exposure threshold concentration identified by Tingey et al. and the chronic exposure concentration

used in the Colstrip study. Therefore, it is unlikely that injury will occur.

Hill et al. (1974) exposed several of the species found on Tract C-a to SO_2. They used concentrations of 0.5, 1.0, 2.0, 4.0, 6.0, and 10.0 ppm SO_2 for two hours in the study. Species found on Tract C-a which were used included serviceberry, sagebrush, cheatgrass, mountain mahogany, rabbitbrush, sweetvetch, Utah juniper, prickly pear cactus, Indian ricegrass, pinyon pine, squirreltail, and snowberry. Of these species, indian ricegrass appeared to be most sensitive and was injured at 0.5 ppm SO_2. The remaining species, with the exception of serviceberry and snowberry, were unaffected by exposure to 1.0 ppm SO_2. After conducting their study with 87 species of native vegetation, the authors concluded that most of the plants required exposure to more than 2 ppm SO_2 for 2 hours to produce injury. Short-term concentrations of SO_2 on Tract C-a will be far below the 0.5 ppm level which Hill et al. found that most of the native plants could tolerate.

In a report assessing up to three years of SO_2 fumigations at Colstrip, Montana, Dodd et al. (1979) stated that no differences in above-ground biomass were found between the plants receiving the SO_2 exposures and the controls. The lowest concentration of SO_2 used in the study was approximately 0.025 ppm and the highest approximately 0.073 ppm. Exposures were conducted throughout the growing season (Preston 1979). The lowest concentration used in the study is greater than the maximum allowable annual average concentration of 0.008 ppm SO_2 (20 $\mu g/m^3$) at Tract C-a. The highest concentration used in the study is higher than the maximum allowable 24-hour SO_2 concentration at Tract C-a. Thus, it is anticipated that the SO_2 emissions at Tract C-a will not have any significant impact on biomass production.

Long-term SO_2 injury thresholds have received limited assessment (Guderian and Stratmann 1968, Guderian 1960, Stratmann 1963). These studies showed growth and yield impacts occurring at seven month average SO_2 concentrations as low as 0.01 ppm. The maximum annual SO_2 concentration allowable

around Tract C-a is 0.008 ppm (20 $\mu g/m^3$). Model predictions are considerably less than this value. Thus, it is unlikely that the long-term SO_2 concentrations at the site will produce impacts to vegetation on Tract C-a.

Le Blanc and Rao (1973) established SO_2 levels which they believe represent thresholds for injury to lichens which are highly sensitive to SO_2. They proposed long-term average concentrations of 0.03 ppm as an acute injury threshold and concentrations between 0.006 and 0.03 ppm as a chronic injury threshold. The maximum short term (24 hour) concentration of SO_2 allowable at Tract C-a is 0.035 ppm (91 $\mu g/m^3$) and the maximum allowable annual SO_2 concentration is 0.008 ppm. Thus it would appear that there is a slight potential for acute injury to foliose lichens at the maximum allowable SO_2 levels. However, many of the lichens present on Tract C-a are crustose, saxicolous types (forming shallow layers on rocks). Le Blanc and Rao (1975) state that crustose lichen growth forms are generally more resistent to SO_2 injury than foliose and fruticose lichen types.

Although some research has indicated a potential for vegetative injury resulting from interaction of SO_2 and O_3, the background concentrations of ozone (O_3) on Tract C-a and vicinity is far below the levels considered to be phytotoxic, and also below the level which will likely interact with SO_2 to produce vegetation injury.

7.2.3.2 Flat Tops Wilderness Area. The Flat Tops Wilderness is composed primarily of alpine and subalpine habitats.

The maximum SO_2 levels predicted for the Flat Tops Wilderness Area will satisfy PSD Class I standards. The majority of the plants found in the Flat Tops Wilderness area have never been included in studies of the effects of SO_2. Consequently their SO_2 injury thresholds are unknown.

The maximum levels of SO_2 allowed for the Flat Tops Wilderness Area are below injury thresholds established for lichens by LeBlanc and Rao (1973). Neither the acute injury threshold of 0.03 ppm or the chronic injury threshold of 0.006 ppm should be exceeded. Thus, lichens, the most

SO_2-sensitive plants in the area, should not be injured by the maximum SO_2 levels allowable.

Sec. 8.0

8.0 IMPACTS DUE TO SECONDARY GROWTH

8.1 Tract C-a Employment and Population Projections

The total population influx resulting from the Lurgi Demonstration Project is a function of the level of local vs. non-local employment, the relationship between basic and non-basic employment, and the demographic characteristics of employees and related populations. The projections were derived from information provided by RBOSC regarding anticipated manpower requirements, historic data from the existing experimental project, and from several sources documenting typical factors associated with other energy projects in Northwestern Colorado and similar regions (Briscoe, et al. 1979; Colorado West Area Council of Governments, 1980; Denver Research Institute 1975; and Old West Regional Commission 1975).

Project construction and operation employment levels are shown in Table 8-1, together with a summary of total population impacts and distribution scenarios. It was assumed, based on characteristics of the existing Tract C-a work force, that approximately 50 percent of both base (project) and non-base (service) positions with be filled by local residents. The total population influx can then be determined by applying family size and marital status factors to the various employment groups (e.g. construction, operation, service). These factors were derived from the Colorado West Area Council of Governments projection series for northwest Colorado and from empirical studies in the region (Old West Regional Commission 1975, Denver Research Institute 1975). Two scenarios were developed to reflect the alternative population levels and distributions associated with either distribution of employees to existing communities or development of a construction camp designed to house 100+ construction workers in bachelor quarters. The differences in population levels reflect the assumption that if a construction camp were built, a lower percentage of construction workers would bring their families with them. Therefore, the demand for secondary (service) employment would be correspondingly reduced. It should be noted that these alternative projections apply only to the construction period (1981-1983), with identical population levels and distributions forecast for the operations phase.

TABLE 8-1

SUMMARY OF TRACT C-a EMPLOYMENT AND POPULATION PROJECTIONS

	May Dec 1981	1982	1983	1984	1985	1986
Project Employment						
Construction	200	274	150	--	--	--
Operation	--	143	248	248	248	248
Subtotal	200	417	398	248	248	248
Total Service Employment	120	380	462	372	372	372
TOTAL EMPLOYMENT	320	797	860	620	620	620
Non-local (Imported Employment) with Construction Camp						
Project (Base)	100	209	199	124	124	124
Service (Non-Base)	27	149	209	186	186	186
TOTAL NON-LOCAL EMPLOYMENT	127	358	408	310	310	310
Non-Local (Imported Employment) without Construction Camp						
Project (Base)	100	209	199	124	124	124
Service (Non-Base)	60	190	231	186	186	186
TOTAL NON-LOCAL EMPLOYMENT	160	399	430	310	310	310
TOTAL POPULATION INCREASE						
With Construction Camp	184	668	857	718	718	718
Without Construction Camp	336	877	970	718	718	718
POPULATION DISTRIBUTIONS With Construction Camp						
Rifle	53	418	636	596	596	596
Meeker	8	66	100	93	93	93
Rangely	3	20	31	29	29	29
Construction Camp	120	164	91	--	--	--
Without Construction Camp						
Rifle	279	728	805	596	596	596
Meeker	44	114	126	93	93	93
Rangley	13	35	39	29	29	29

The population distribution for the "without construction camp" scenario was based on the existing distribution of Tract C-a employees.

Based on the above factors and assumptions delineated below, it was estimated that the total population influx will peak in 1983 at 857 people with the camp and at 970 people without the camp. This would level off to 718 people through the operations phase (1984 through 1986). Rifle would experience the largest impact, ranging from 636 to 805 in 1983 and leveling off to 596 people in 1984. Meeker and Rangely would experience much lower levels of impact, particularly if the construction camp is built. These distribution scenarios assume that no Rangely access road is built and that the majority of transportation impacts and related air quality effects will occur along existing access routes. See Appendix E for detailed tables and calculations.

ASSUMPTIONS

Item		Sources
Local/Non-Local Employment Ratio-50%		RBOSC existing project data
Base/Non-Base (Service) Employment Multipliers		Briscoe, Maphis, Murray & Lamont, 1979
Construction	0.6	
Operation	1.5	
Household/Family Size Characteristics		
Parent with Families present/single		Denver Research Institute, 1975
Construction/Service	60%/40%	
Operation	85%/15%	
Family size		
Construction & Operation	2.71	CO West Area Council of Govts. 1980
Service	3.04	

Population Distribution (without Const. Camp)		RBOSC
Rifle	83%	existing project
Meeker	13%	data
Rangly	4%	

8.2 Air Quality Impacts Due to Secondary Growth

The increased population that will result from the Lurgi Demonstration Project will contribute to the emissions of various air pollutants in the general area. The project-related population increase fluctuates throughout the life of the project, but reaches a maximum value in 1983 of approximately 970 persons. The average family size has been estimated to be 2.71 persons, thus a total of 358 new family units are projected to move to the project area.

Two sources of emission will result from this projected population increase

- vehicular traffic, and
- space heating.

The emissions from vehicular traffic have been calculated assuming 2.0 vehicles per family, 12,000 miles per vehicle-year and emission factors taken from the EPA document AP-42 (U.S. EPA 1977). A summary of the vehicular emissions is shown in Table 8-2. The emissions from space heating were calculated assuming each family to be a residential natural gas customer and a value of 126.5×10^6 Btu/yr. of natural gas purchase for each customer (U.S. Department of Commerce, 1978). This value represents a Colorado average gas consumption. Emissions were then calculated using emission factors from the EPA document AP-42 (U.S. EPA, 1977). A summary of space heating emissions is shown in Table 8-3.

The ambient impacts from these emissions were calculated with a simple box model. The emissions were assumed to enter uniformly in a vertical cross-section of a box 2 kilometers wide (roughly intended to simulate the size of Rifle, Colorado) and 500 meters high (a conservatively low value of the mixing depth).

TABLE 8-2

SECONDARY EMISSIONS FROM VEHICULAR TRAFFIC

Pollutant	Emission Rate (ton/yr)
Sulfur Dioxide	1.24
Oxides of Nitrogen	7.03
Particulate Matter	5.13
Carbon Monoxide	24.14
Hydrocarbons (total as methane)	7.03

TABLE 8-3

SECONDARY EMISSIONS FROM SPACE HEATING

Pollutant	Emission Rate (ton/yr)
Sulfur Dioxide	0.02
Oxides of Nitrogen	2.26
Particulate Matter	0.23
Carbon Monoxide	0.45
Hydrocarbon (total as methane)	0.18

TABLE 8-4

CALCULATED IMPACTS FROM SECONDARY GROWTH*

Pollutant	Average Concentration ($\mu g/m^2$)**
Sulfur Dioxide	0.01
Oxides of Nitrogen	0.09
Total Suspended Particulates	0.05
Carbon Monoxide	0.24
Hydrocarbons	0.07

*Calculated using the emissions of Table 8-1 and 8-2 and using the following equation:

$$X = \frac{Q \times 10^6}{uMs}$$

Where
X = ambient concentration, $\mu g/m^3$
Q = emission rate, g/sec
u = wind speed, m/sec
M = mixing depth, m
s = length of box side facing the wind, m

**Values are not specific to any averaging time, but can be viewed as maximum values, rather than long-term averages due to the conservative assumptions on the box width and mixing depth.

Finally, the emissions were assumed to be dispersed by a 3 meter per second wind (a conservatively low value). Resultant concentrations are shown in Table 8-4. As shown in the Table, all values are extremely low and well below the level of detectability of most monitoring equipment.

Sec. 9.0

9.0 BEST AVAILABLE CONTROL TECHNOLOGY (BACT)

This portion of the PSD Application deals primarily with major atmospheric emissions from the Lurgi Demonstration Project and the methods of control. Descriptions of the facilities and operations given herein will be limited to those directly related to the emission sources and control technologies. Refer to the Development Plan of the Lurgi Demonstration Project for a more detailed description.

Reference should also be made to appropriate sections of the Air Quality Impacts Review of the PSD Permit Application for specific emission data (emission inventory) and their effects on air quality.

The EPA Region VIII Interim Policy Paper on Air Quality Review of Surface Mining Operations (1979) was used as a guide for BACT practice.

9.1 ROADS AND CONSTRUCTION AREAS

The primary air pollutant generated by construction and mining operations will be fugitive dust. Proper abatement and preventative measures will be provided to prevent fugitive dust from unpaved roads and other disturbed areas in the project area during initial construction activities.

9.1.1 Roads

Traffic will be confined to specified roads, corridors, and designated construction areas to minimize land disturbance. Routing, speed control, and closure of construction areas to extraneous traffic will reduce the total dust load in the airshed. The use of off-road vehicles will be restricted to necessary areas of the construction sites. During road construction the roads and parking areas will be watered frequently with trucks and/or sprinkler systems to allay fugitive dust. The road base will be compacted 90% in accordance with the Proctor test to stabilize the roadbed and help reduce dust emissions. Loose debris will be graded from the roads to maintain a hard, smooth driving surface. The application of

chemicals to the roadbed for stabilization will be used, if proven effective.

RBOSC has tested a number of dust suppressant chemicals to control fugitive emissions on roads and disturbed areas of Tract C-a. Most, including Coherex, have not been effective on roads carrying high traffic volume. Recently, encouraging results have been obtained on high traffic areas using lignon sulfonate, a penetrating chemical derived from the pulp and paper industry. RBOSC will continue to test this and other dust suppressants to determine the most effective method, in combination with watering, to control fugitive dust generation from roads and other disturbed areas. The estimated application rate will be one gallon of 20 percent lignosulfonate (ORZAN AL-50 or equivalent) per square yard of road surface for the initial application. The lignosulfonate will be reapplied as needed approximately every two to four months at an application rate of 0.3 to 0.5 gallons of 20 percent lignosulfonate per square yard of road surface.

It is estimated that the water application rate for roads treated with dust suppressants will be approximately 0.2 gal/yd^2-shift. The amount applied will vary, however, depending on the amount and type of vehicular traffic and on weather conditions.

9.1.2 Construction Areas

Development will be coordinated so that lands are disturbed only when necessary and damage to existing vegetation is minimized. Straw, mulch or chemical dust suppressants will be used if necessary to prevent excessive erosion by wind or water until vegetation can be established.

During construction of the processing facility, access areas will be watered frequently with water trucks to control fugitive dust around work areas. The processing areas and access road will be paved or covered with gravel as soon as the construction activities will permit. Compaction and the use of dust palliatives and retardants will be used as needed, to prevent blowing of soils until paving, revegetation or

other permanent cover is in place. The topsoil removed from the mine and other disturbed areas will be stockpiled and revegetated. Revegetation will be completed as soon as practical after the pile is brought to its final configuration. Mulches or chemical dust suppressants can be applied as temporary measures if deemed necessary.

The concrete batch plant is another source of particulate emissions. Bag filters will be used to remove nearly all the particulates from this source. Bag filters will be installed on sand and aggregate storage bins, cement storage silos, weight hoppers, and mixers. (BACT)

9.2 MINING OPERATIONS

Proposed mining operations for the Lurgi Demonstration Project are described in detail in Section 2 of the Development Plan. Particulate emissions (fugitive dust) are of primary concern for the mining operations. Major emission sources and the control technologies to be applied are given below. In cases where the control methods vary from EPA Region VIII past practices, reasons for the variations are given.

9.2.1 Drilling

Dust from drilling operations will be controlled by water injection, and by using standard cyclone collectors on the rotary drills. Water injection will be controlled manually by the drill operator to maintain a dust-free operation. (BACT)

9.2.2 Blasting

Dust will be controlled by employing good blasting practices such as designing blasts to prevent overshooting. Blasting will be done at shift changes so that blasting effects will occur infrequently and for short durations. The dust generated by blasting of ore should also be reduced due to the high moisture content of this material because of its proximity to the upper aquifer. (BACT)

9.2.3 Overburden and Oil Shale Removal

Truck and shovel methods will be used for overburden and oil shale removal. In loading the materials into haul trucks, the fall distance from the bucket to the bed of the truck will be minimized, thus preventing excessive emissions. For oil shale removal operations, it is anticipated that low emissions of dust will result because of the high moisture content of the shale removed from the Mahogany ore zone and the limited amount of fines generated by the blasting and removal operations (BACT).

Overburden material removed from the mine site will be used for fill material at the mine facilities area and the haul road, for constructing the containment dikes of the processed shale disposal area or will be placed in the overburden stockpile adjacent to the open pit.

Overburden used as fill at the mine facilities area will be compacted and watered to control dust emission. Dust suppressant chemicals and other control measures will be used where appropriate. Areas that will remain undisturbed after construction activities are completed will be topsoiled and revegetated. (BACT)

The fill areas along the haul roads will be primarily large angular rock, and, thus, these slopes should not be a significant source of fugitive emissions.

Watering of the overburden material after it is spread along the corridor will help to control dust from this source.

The overburden material used in constructing the containment dike for the processed shale disposal area will be compacted for stability and watered for dust control. The outslopes of these dikes will be topsoiled and revegetated as soon as construction activities on the dike slopes are completed (BACT).

9.2.4 Stockpiling of ROM Oil Shale

The mined oil shale will be dumped by end dump trucks onto an oil shale stockpile located adjacent to the Lurgi processing facilities. Enclosure of the oil shale stockpile is not being considered because it is anticipated that the stockpile will not be a significant source of dust due to the low percentage of fine materials. Water application to the stockpile is not being considered as a possible dust control measure because of problems that would occur in the handling and crushing of a wet material.

9.2.5 Road Maintenance

Loose debris will be graded from the roads at all times. Hard, smooth driving surface will be maintained. Dust suppressant chemicals will be applied, if proven effective. The estimated rate of application will be one-third to one-half gallon of 20 percent lignosulfonate (ORZAN AL-50 or equivalent) per square yard of road surface. (BACT)

9.2.6 Disturbed Areas (Mine-related)

If areas disturbed as a result of mining operations can be isolated and not re-disturbed for long periods, vegetation, mulch or dust suppressant chemicals will be used for dust control. (BACT)

9.2.7 Topsoil Stockpile

Rapid revegetation will be used to stabilize the topsoil stockpile. (BACT)

The emission control technologies to be used for mining operations are summarized in Table 9-1.

9.3 RETORT FEED PREPARATION

The preparation of ROM oil shale for use as retort feed consists of the following operations:

TABLE 9-1

MINING OPERATIONS - EMISSION CONTROL TECHNOLOGY

Operation	BACT Practice (Note 1)	Proposed Control Technology			Remark
		Description	Control Efficiency - %	Relating to BACT	
Drilling	Use of bag type collector on air drill, or water injected	Using water injected drills, or cyclone collection on rotary drills	90	BACT	
Blasting	Minimize area to be blasted prevent overshooting	Minimize blasting area and design blasts to prevent overshooting	0	BACT	
Overburden and Oil Shale Removal	Minimize fall distance of material	Minimize fall distance of material	0	BACT	
Overburden and Topsoil Stockpile Erosion	Temporary vegetation, mulch or chemical dust suppressant	Rapid revegetation	75	BACT	
Stockpiling of ROM Oil Shale	Not Specified	None	0	-	BACT for coal storage is enclosure against wind erosion, which is not applicable to ROM Oil Shale
Haul Roads	Speed controls and chemical stabilizer worked into the road	Maximum speed-25 mph and stabilizer worked into the roadbed.	85	BACT	
Road Maintenance	Removal of loose debris, grading and chemical stabilization of roadbed	Removal of loose debris, grading and application of chemical dust suppressant	0	BACT	
Disturbed Areas	Chemical dust suppressants, mulch, revegetation, and minimizing the area disturbed	Vegetation, mulch, or dust suppressant chemicals	75	BACT	
Topsoil Stockpile Erosion	Rapid vegetation, or mulch, or chemical dust suppressant or establish wind breaks	Rapid vegetation	75	BACT	

Note 1: Based on EPA Region VIII, Interim Policy paper on Air Quality Review of Surface Mining Operations pursuant to PSD regulations, 40 CFR 52.21.

- Raw shale load-in (to crusher) - This involves reclaiming ROM oil shale from the ROM stockpiles and feed to the primary crusher.

- Shale crushing - This includes the primary crushing, screening, secondary crushing, and transport by conveyors.

- Crushed shale feed to Lurgi retort - This includes loading the crushed oil shale to the storage pile, crushed shale storage, reclaiming from the storage pile, and feed to the Lurgi retort.

- Details of the oil shale retort feed preparation are included in Section 3 of the Development Plan.

The major atmospheric emission from the retort feed preparation is fugitive dust. BACT will be applied to all operations for retort feed preparation to control dust emissions as described below.

9.3.1 Reclaiming from ROM Oil Shale Stockpile

Oil shale will be reclaimed from the ROM oil shale stockpile by a front-end loader and then dumped to the feed hoppers, each equipped with a grizzly screen to control the size of shale to the crusher.

Particulate emissions (dust) will be controlled by maintaining minimum fall distance in the reclaiming and dumping operations (BACT).

9.3.2 Crushing and Screening

The primary crushers, vibrating screens, secondary crushers, and all transfer points of conveyors will be maintained at negative pressure by a centralized baghouse filter cleaning system. (BACT)

Beltavators used to convey the crusher and screen feed shale will trap the conveyed material between two belts in elevated sections, thus minimizing dust emissions. Other transfer conveyors will be fully covered. (BACT)

9.3.3 Crushed Oil Shale Storage

Crushed and screened oil shale will be conveyed to and stored in the crushed oil shale storage building by a belt-tripper conveyor. Wind erosion or wind blown dust problems will not occur, because the crushed shale storage pile is totally enclosed in a building. The building ventilation system will be equipped with air filters to prevent particulate emissions to the atmosphere. (BACT)

9.3.4 Retort Feed

A rotary plow feeder will be used to remove crushed shale from the storage pile onto a connecting belt. This tunnel type feeder will not cause dust emission in the crushed shale storage building. (Better than BACT)

The collecting belt conveyor, a beltavator unit, will feed crushed shale to the Lurgi retort feed hopper. The feed hopper as well as the sample cutter weigh belt feed, and the transfer point of the beltavator will be connected to a bag filter type dust collection unit to control fugitive dust. (BACT)

The emission control technologies proposed for the retort feed preparation system are summarized in Table 9-2.

9.4 LURGI PROCESSING AND SUPPORT FACILITIES

The Lurgi Processing operations are described in Section 4, Chapter 3 of the Development Plan.

9.4.1 Processing

Three possible sources of atmospheric emissions exist in the processing facility. They are the L-R flue gas, fugitive dust at the processed shale discharge and transfer points, and emissions from storage tanks. The following is a discussion of emission controls for the Lurgi flue gas. The approximate concentrations of SO_2, NO_x, and particulates in the flue gas of the Lurgi retort are shown in Table 7-5-3 of the Lurgi Demonstration Project Report.

TABLE 9-2

RETORT FEEO OIL SHALE PREPARATION - EMISSION CONTROL TECHNOLOGY

Operation	BACT Practice (Note 1)	Proposed Control Technology			Remark
		Description	Control Efficiency - %	Relating to BACT	
(1) (to crusher)	Raw Shale Load-in	Minimum fall distance	Minimum fall distance	0 BACT	
(2)	Shale Crushing				
a) Primary crusher	Baghouse or Equivalent	Baghouse	99	BACT	Centralized baghouse system
b) Screening feed hopper	Baghouse or Equivalent	Baghouse	99	BACT	Centralized baghouse system
c) Vibrating screens	Baghouse or Equivalent	Baghouse	99	BACT	Centralized baghouse system
d) Secondary crusher	Baghouse or Equivalent	Baghouse	99	BACT	Centralized baghouse system
e) Conveyor	Fully covered	Fully covered	99	BACT	Centralized baghouse system
(3)	Crushed Shale Feed to Lurgi				
a) Loading to storage pile	Baghouse	Baghouse	99	BACT	Centralized baghouse system
b) Storage Pile Erosion	Enclosed with filters	Enclosed with filters	0	BACT	Centralized baghouse system
c) Reclaiming (load-out) from storage pile	Minimum fall distance	Rotary plow	99	Better than	Using drive-below plow arrangement eliminating dust emission
d) Conveying to retort feed	Fully covered	Fully covered	99	BACT	
e) Retort feed	Baghouse	Baghouse	99	BACT	

Note 1: Based on EPA Region VIII, Interim Policy paper on Air Quality Review of Surface Mining Operations pursuant to PSD regulations, 40 CFR 52.21.

Due to the nature of Colorado oil shale deposits and the design of the Lurgi retort, the process is essentially a self-contained stack gas scrubber. In the Lurgi retort process, the recycled processed shale along with fresh shale which has just been retorted flows from the surge bin into the vertical lift pipe for combustion of the residual carbon. Combustion takes place in the lift pipe after preheated air contacts the coke on the spent shale. This combustion step converts the sulfur in the spent shale to SO_2 and also converts some of the naturally occuring carbonates in the oil shale to oxides. The oxides then react with the SO_2 in the presence of excess oxygen to form sulfates. The following equation is an example of this oxidation process:

Carbonate decomposition: $CaCO_3 \rightarrow CaO + CO_2$

SO_2 Reaction: $CaO + SO_2 + \frac{1}{2}O_2 \rightarrow CaSO_4$

The conditions in the lift pipe are such that at least 93 percent of the available sulfur from combustion is converted into the sulfate form with the balance passing out in the flue gas stream in a concentration of less than 30 ppm as SO_2. Any sulfur in auxiliary fuel (shale oil liquids, shale oil product gas or natural gas) is likewise converted to the sulfate in the lift pipe.

The efficient removal of sulfur is the result of the large excess of oxides compared to stoichiometric requirements to oxidize the SO_2 to sulfates.

Because the lift pipe will run at relatively low temperatures, the NO_x content of the flue gas generated in the lift pipe will be less than 300 ppm. The NO_x is generated almost exclusively from organic nitrogen compounds present in the coke burned in the lift pipe; essentially none results from atmospheric nitrogen. The NO_x concentration is not expected to increase even though operating temperatures in the lift pipe may deviate somewhat from the design temperature of 1,240°F because significant quantities of NO_x are not formed from atmospheric nitrogen at these temperatures.

Carbon monoxide, CO, will also result from combustion in the lift pipe. The concentration of CO is expected to be less than 90 ppm, however, since the lift pipe runs at a temperature that is sufficiently high to assure low CO concentrations, and the flue gas contains about 5 percent oxygen.

A substantial portion of the processed shale is dropped out of the flue gas in the collecting bin and is circulated back to the retort to supply the necessary process heat. The flue gas and the remaining portion of the processed shale is carried from the collecting bin to the heat recovery system for preheating air and generating steam. After the flue gas has been cooled to about 570°F, it passes through a cyclone that is designed to remove approximately 56 percent of the remaining dust present in the flue gas.

Flue gas leaving the cyclones passes into a conditioner where water vapor from the cooling conveyor (which is used to cool processed shale to the discharge temperature) increases the humidity of the flue gas. This humidified gas passes into the electrostatic precipitator where more than 99.9 percent of the remaining solids are removed. The dedusted flue gas from the electrostatic precipitator then exits the stack.

Overall recovery of the dust from the flue gas is approximately 99.98 percent. As the flue gas passes through the dust removal equipment the dust concentration is reduced from 1.07 pounds of solids per pound of flue gas to approximately 1.5×10^{-4} lb of dust per pound of flue gas (150 ppm). The total dust discharged in the flue gas is only 41 pound per hour.

The use of bag filters, which, in many cases, is as effective as electrostatic precipitators in removing particulates, cannot be considered for the demonstration unit because the flue gas temperature is designed for 460°F. This relatively high exit temperature is near the top of the range specified for most bag filter fabrics available.

During the test runs made on this demonstration unit, RBOSC will attempt to optimize the conditions within the lift pipe to minimize the overall discharge of SO_2, NO_x and CO consistent with good oil recovery from the

retort. While we will also optimize the operation of the incinerator and the scrubber on the distillation gas, this is not of primary importance since, in a commercial venture, this product will not be incinerated but rather used within the retorting/upgrading complex either as a feed material for hydrogen production, or as a fuel for the total complex.

9.4.2 Support Facilities Emission Control

Support facilities that will generate atmospheric emissions include the product gas incinerator, steam generation boilers, diesel engine drives for the emergency power generator and firewater pump, the hot oil heater, and emergency flare. Emissions will also occur from product oil, diesel fuel, gasoline, and waste oil storage tanks due to vapor losses.

The above-mentioned emission sources, with the exception of the product gas incinerator, will not have significant SO_2 emissions. The incinerator will have an SO_2 scrubber with a drop separator, a mist eliminator, and a steam reheater. The latter will increase the temperature of the near saturated flue gases to approximately 220°F to avoid stack condensation. Specifications for this scrubber are included in Appendix F.

The SO_2 removal in the scrubber is accomplished by the addition of sodium hydroxide or sodium carbonate to the scrubber solution.

The emission control technologies to be used for the Lurgi flue gas and the product gas incinerator are summarized in Table 9-3.

9.5 PROCESSED SHALE DISPOSAL

Processed shale disposal operations are described in detail in Section 5 of the Development Plan.

The processed shale will be moisturized immediately after discharge from the Lurgi processed shale cooler. It will be transported to the processed shale disposal area by a belt conveyor system, which includes trippers and

TABLE 9-3

LURGI PROCESSING AND SUPPORT FACILITIES - EMISSION CONTROL TECHNOLOGIES

OPERATION		PROCESSING UNIT PARTICULATE EMISSION LURGI FLUE GAS	SUPPORT FACILITIES SO_2 EMISSION PRODUCT GAS INCINERATOR
Stack Height/Diameter	(ft/ft)	300/8	310/6.5
Flue Gas Flow	(pph)	266,500	205,000
Exit Temperature	(^oF)	460	220
Control Devices		Cyclone and electrostatic precipitator in series	SO_2 scrubber
Control Device Efficiency	(%)	99.98	80 (Note 1)
Estimate Emission	(pph)	41 (Particulates) 0.035 grain/ACF	10 20 ppm (Vol.)

Note 1: This control efficiency is limited by the low SO_2 concentration in the scrubber influent. 20 ppm (vol.) in the stack flue gas represents the minimum value achievable BACT.

stackers to distribute the processed shale into the diked (containment) area.

To control particulate emissions, the conveyors carrying processed shale will be covered, and all transfer points will be provided with water sprays to control dust emissions. Additional water can be sprayed onto the processed shale as it is delivered to the disposal area, if necessary. (BACT)

Topsoil cover and revegetation on the exterior dike slopes will be carried out once the dike is completed. Watering will be done as required during the construction stage of the dikes. Topsoil cover and revegetation will also be carried out on the processed shale area once it is completed. (BACT)

Table 9-4 summarizes the emission control technologies to be used for processed shale disposal.

TABLE 9-4

PROCESSED SHALE DISPOSAL - EMISSION CONTROL TECHNOLOGY

Operation	BACT Practice (Note 1)	Proposed Control Technology			Remark
		Description	Control Efficiency - %	Relating to BACT	
Processed shale transport	Fully covered conveyors, dust control at transfer points	Fully covered conveyors water spray at all transfer points	99	BACT	
Containment area for processed shale	Not specified (see Remark)	Topsoil cover and vegetation on exterior dike walls and completed disposal area	0	BACT	Use BACT for disturbed areas as a guide

Note 1: Based on EPA Region VIII, Interim Policy paper on Air Quality Review of Surface Mining Operations pursuant to PSD regulations, 40 CFR 52.21.

Sec. 10.0

10.0 GOOD ENGINEERING PRACTICE (GEP) FOR STACK HEIGHT AND ASSESSMENT OF DE MINIMIS POLLUTANTS

The following is a brief discussion of the design of emission stacks to comply with the Good Engineering Practice (GEP) guidelines and a preliminary assessment of the de minimis pollutant as specified in 40 CFR 51.24 and 52.21.

10.1 Good Engineering Practice (GEP)

Section 123 of the Clean Air Act Amendments of 1977 addresses GEP stack height considerations. EPA draft guidelines (EPA 1979) provide a formula to calculate the maximum creditable stack height (GEP) which a source may use in calculating the air quality impact. The GEP formulation is as follows:

$H_G = H + 1.5\ L$

H_G = GEP stack height

H = Height of the structure or nearby structure

L = Lesser dimension (height or width) of the structure or nearby structure.

The Lurgi retort is 273 ft. tall and 35 ft. wide. Based on the formula, GEP stack height is 325 ft. Since the Lurgi retort stack will be 300 feet tall, the stack design conforms to GEP guidelines.

Excessive concentrations of air pollutants near the retort due to aerodynamic downwash should not be a problem, because the top of the Lurgi structure will not be enclosed above the 100 ft. level. In addition, the retort structure is very tall and narrow, and adjacent buildings are less than 100 ft. tall.

The other major stationary emission source for the Lurgi Demonstration Project will be the incinerator and SO_2 removal system. The stack for this source will not be enclosed and will be 310 ft. tall. The incinerator stack will be approximately 50 feet from the Lurgi Retort structure. No

significant downwash or wake problems are anticipated due to the proximity of the Lurgi retort structure, for the reasons delineated above.

10.2 De minimis Pollutants

Little data are available presently on the concentration of the de minimis pollutants in the emissions from the Lurgi surface retort. Recently Lurgi-Frankfurt conducted pilot plants tests using shale from Tract C-b. RBOSC requested that flue emissions from this test run be analyzed for the following de minimis pollutants: lead, asbestos, mercury, beryllium, and fluorides. Unfortunately, Lurgi's laboratory in Frankfurt does not have the capability to conduct analyses for these pollutants. Lurgi will be conducting another pilot scale test in February or March of 1981, using Tract C-b shale, and is planning to subcontract the laboratory analysis in order to determine the concentrations of the de minimis pollutants. These data will be forwarded to EPA immediately after receipt by RBOSC.

Based on existing data, RBOSC does not anticipate that any of the de minimis values will be exceeded. Because of the nature of the retorting process and the raw material (oil shale), no emissions of vinyl chloride, asbestos, or sulfuric acid mist are anticipated. Emissions of reduced sulfur species should be minimal due to the excess oxygen used in the combustion process, and the natural sulfur scrubbing characteristics of the oxides produced during retorting.

The concentration of fluorides in oil shale is generally high. Average concentration reported by the USGS for raw shale from Tract C-a was 1290 ppm. Samples of oil shale retorted in the Fischer assay show that there is no significant loss of fluoride from the solid fraction during retorting because most of the fluoride in oil shale is inorganically bound (Saether et al 1980). Comparison of fluoride concentrations in fresh and processed shale from Tract C-a indicated that the concentration in processed shale is over 95% of that in the fresh shale.

Concentrations of mercury, beryllium and lead in oil shale are generally quite low. USGS reported that the average concentration of mercury for

samples of Tract C-a oil shale was 0.14 ppm. Average lead concentrations in oil shale are usually from 20 to 30 ppm and beryllium concentrations of 1.5 to 2 ppm have been reported. RBOSC data indicate that there is no significant loss of mercury during retorting. Although similar data are not available for beryllium and lead, it is anticipated that these metals will also be retained in the solid phase and emissions will be substantially below the de minimis levels.

Sec. 11.0

11.0 LITERATURE CITED

Benkley, C. W. and L. L. Schulman. 1979. Estimating Hourly Mixing Depths from Historical Meteorological Data. Journal of Applied Meteorology 18, pp. 772-780.

Briscoe, Maphis, Murray & Lamont. 1979. Action Handbook: Managing Growth in the Small Community. Prepared for the EPA.

Colorado West Area Council of Governments. 1980. "Region XI Population Projections - Municipal and County Population Projections: 1980-2000".

Colorado Department of Health. Emission Factors for Mining Operations. not dated

Davis, D. D. and R. G. Wilhour. 1976. Susceptibility of woody plants to sulfur dioxide and photochemical oxidants. U.S. EPA, Corvallis, Oregon. EPA-600/3-76702.

Denver Research Institute. 1975. Boom Town Growth Management. Prepared by John S. Gilmore and Mary K. Duff.

Dodd, J. L., W. K. Lavenroth, G. L. Thor, and M. B. Coughenour. 1979. Effects of chronic low level SO_2 exposure on producers and litter dynamics. In: The Bioenvironmental Impacts of a Coal-Fired Power Plant. Fourth Interim Report. Preston, E. M. and T. L. Gullett (eds.). U.S. Environmental Protection Agency. Corvallis, Oregon. OPA-600/3-79-044.

Egan, B. A. 1975. Turbulent Diffusion in Complex Terrain. Workshop on Air Pollution Meteorology and Environmental Assessment, American Meteorological Society, 29 September - 3 October 1975. Boston, MA.

Ermak, D. L. 1977. "An Analytical Model for Air Pollutant Transport and Deposition from a Point Source." Atmospheric Environment 11:231-237.

Environmental Research and Technology, Inc. 1980. "An Analysis of Air Quality and Visibility Effects of the Alton Coal Project" ERT Document No. P-A048-200. August 1980.

Guderian, R. 1960. Zur methodik der ermittlung von SO_2 toleranzgrenzen fuer land und forstwirtschaftliche kulturen im freilandversuch biersdorf (sieg). Straub. 20:334-337.

Guderian R. and H. Stratmann. 1968. Freilandversuche zur ermittlund von schwefeldioxydwirkungen auf die vegetation. Forschungsherichte des Landes Nordrhein-Westfalen. No. 1920. Essen, West Germany.

Heitschmidt, R. K., W. K. Lauenroth, and J. L. Dodd. 1978. Effects of controlled levels of sulfur dioxide on western wheatgrass in a southeastern Montana grassland. J. of Applied Ecology 14:859-868.

LITERATURE CITED (CONTINUED)

Hill, A. C., S. Hill, C. Lamb, and T. W. Barrett. 1974. Sensitivity of native desert vegetation to SO_2 and NO_2 combined. J. Air Pollution Control Association 24:153-157.

Hoffnagle, G. A., B. A. Egan, and B. R. Greene. 1977. Application of Models in Complex Terrain. Joint Conference on Applications of Air Pollution Meteorology - American Meteorological Society. Salt Lake City, UT.

Holzworth, G. R. 1972. Mixing Depths, Wind Speeds and Air Pollution for Selected Areas Throughout the Contiguous United States, Publication No. AP101, EPA, Office of Air Programs, Research Triangle Park, NC.

Hunt, J. C. R., W. H. Snyder, and R. E. Lawson, Jr. 1978. (Preliminary Drafts): Flow Structure and Turbulent Diffusion Around a Three-Dimensional Hill. Part I - Flow Structure. Environmental Sciences Research Laboratory. U.S. EPA. Research Triangle Park, NC.

LeBlanc, F. and D. Rao. 1973. Effects of sulfur dioxide on lichen and moss transplants. Ecology 54:612-328.

LeBlanc, F. and D. Rao. 1975. Effects of air pollutants on lichens and bryophytes. In: Responses of Plants to Air Pollution. Mudd, J. B. and T. T. Kozlowski (eds.). Academic Press, New York.

Marlatt, W. E. 1973. Climate of the Piceance Creek Basin - Rio Blanco and Garfield Counties, Colorado. Prepared for the State of Colorado Thorne Ecological Institute, Boulder, Colorado.

Meyer, L. and R. Nelson. 1975. Adequacy of Regional Atmospheric Data for Specific Predictive Purposes in the Piceance Creek Basin. Environmental OilShale Symposium Proceedings, Colorado School of Mines.

Middleton, J. T., E. F. Darley, and R. F. Brewer. 1958. Damage to vegetation from polluted atmospheres. J. Air Pollution Control Association 8:9-15.

National Academy of Sciences. 1977. Oxides of Nitrogen. National Research Council. Washington, D.C. 333 p.

Nelson, R. 1975. Meteorological Dispersion Potential in the Piceance Creek Basin, Quarterly Report of the Colorado School of Mines.

Occidental and Ashland Oil. 1976. "First Year Environmental Program, Annual Summary and Trends Report, Oil Shale Tract C-b."

Occidental and Ashland Oil. 1977a. "Environmental Baseline Program, Vol. III Final Report, Oil Shale Tract C-b."

LITERATURE CITED (CONTINUED)

Occidental and Ashland Oil. October 1977b. "Environmental Monitoring Program for Oil Shale Tract C-b, Attachment F."

Occidental and Ashland Oil. 1978. "Annual Report for Tract C-b, Volume II."

Occidental Oil Shale. February 1979. "Development Monitoring Program for Oil Shale Tract C-b."

Old West Regional Commission. 1975. Construction Worker Profile.

Preston, E. M. and R. A. Lewis (eds.). 1978. The bioenvironmental impact of a coal-fired power plant, third interim report, Colstrip, Montana. U.S. EPA, Corvallis, Oregon. EPA-600/3-78-021.

Rice, P. M., L. H. Pye, R. Boldi, J. O'Loughlin, P. C. Tourangeau, and C. C. Gordon. 1979. The effects of low level SO_2 exposure on sulfur accumulation and various plant life responses of some major grassland species on the ZAPS sites. In: The Bioenvironmental Impact of a Coal-fired Power Plant, Fourth Interim Report, Colstrip, Montana, Preston, E. M. and T. L. Gullett (eds.). U.S. EPA, Corvallis, Oregon. EPA-600/3-79-044.

Rio Blanco Oil Shale Co. 1977a. "Final Environmental Baseline Report for Tract C-a and Vicinity." RBOSC, Denver, Colorado.

Rio Blanco Oil Shale Co. 1977b. "Rio Blanco Oil Shale Project Detailed Development Plan, Tract C-a, Volume II." RBOSC, Denver, Colorado.

Rio Blanco Oil Shale Co. March 1978. "Modular Development Phase, Monitoring Project - Tract C-a, Volume I." RBOSC, Denver, Colorado.

Rio Blanco Oil Shale Co. March 1980. "Modular Development Phase, Monitoring Report 5, Volume I." RBOSC, Denver, Colorado.

Rio Blanco Oil Shale Co. 1980. Technical Modification to the Revised Detailed Development Plan. RBOSC, Denver, Colorado.

Saether, O.M., et al. 1980. Fluorine: Its Mineralogical Residence in the Mahogany Zone of the Green River Formation, Piceance Creek Basin, Colorado. In: Trace Elements in Oil Shale. Progress Report 1979-1980. Center for Environmental Sciences. University of Colorado. Denver. DOE Contract No. EV-10298:256-280.

Sehmel, G. and Hodgson. 1974. "Atmospheric Surface Exchange of Particle and Gaseous Pollutants." R. Engelman and G. Sehmel (eds.). U.S. Atomic Energy Symposium, Series No. 38, Washington, D.C., U.S. Government Printing Office.

LITERATURE CITED (CONTINUED)

Slowik, A. A., J. M. Austin, and G. N. Pica. 1977. Plume Dispersion Modeling in Complex Terrain Under Stable Atmospheric Conditions. APCA Annual Meeting, Toronto, Canada.

Smedman-Högström, A. and U. Högström. 1978. "A Practical Method for Determining Wind Frequency Distributions for the Lowest 200 m from Routine Meteorological Data." Jour. of Applied Meteorology 17: 942-954.

Stratmann, H. 1963. Freilandversuche zur ermittlung von schwefeldioxid-workungen aug die vegetation. II. Messung und bewertund der SO_2 immissionnen. Forschungsberichte des Landes Nordrehein Westfalen. No. 1984. Essen, West Germany.

Taylor, O. C. 1968. Effects of oxidant air pollutants. J. Occupational Medicine 10:485-499.

Taylor, O. C., C. R. Thompson, D. T. Tingey, and R. A. Reinhart. 1975. Oxides of nitrogen. In: Responses to Plants to Air Pollution. J. B. Mudd and T. T. Kozlanski (eds.). Academic Press, New York. 383 p.

Tingey, D. T., R. W. Field, and L. Bard. 1976. Physiological responses of vegetation to coal-fired power plant emissions. In: The Bio-environmental Impact of a Coal-fired Power Plant. Second Interim Report. Lewis, R. A., N. R. Glass, and A. S. Lefohn (eds.). U.S. EPA, Corvallis, Oregon. EPA-600/3-76-013.

Turner, D. B. 1969. Workbook of Atmospheric Dispersion Estimates. U.S. Department HEW, Public Health Service, NAPCA, Cincinnati, OH.

U.S. Department of Commerce. 1978. Statistical Abstract of the United States. 99th Ed. p. 619. Bureau of the Census.

U.S. Environmental Protection Agency, OAQPS. 1977. Compilation of Air Pollutant Emission Factors. Third Edition, August 1977.

U.S. Environmental Protection Agency. May 1977. "EPA Quality Assurance Handbook, Air Pollution Measurement, Volume I."

U.S. Environmental Protection Agency. April 1978. "Air Quality Criteria for Ozone and Other Photochemical Oxidants." EPA-600/8-78-004.

U.S. Environmental Protection Agency, Region VIII. 1979. Compilation of Past Practices and Interpretations by EPA Region VIII on the Air Quality Review of Surface Mining Operations. December 10, 1979.

U.S. Environmental Protection Agency. May 1980. "Workbook for Estimating Visibility Impairment." EPA 68-02-3337.

LITERATURE CITED (CONTINUED)

Wyoming Department of Environmental Quality. 1979. Permit Application Guidelines - Surface Mining. January 1979.

Appendix A

APPENDIX A
MODEL DESCRIPTIONS

APPENDIX A-1

DESCRIPTION OF THE SEQUENTIAL VALLEY MODEL

The sequential VALLEY model is an adaptation of the EPA guideline model, VALLEY (EPA 1977), designed to accept sequential hourly meteorological inputs. The sequential VALLEY model's computation algorithms are identical to those of VALLEY except for certain specific modifications designed to overcome some of the extreme built-in overprediction that limits the ability of the model to realistically predict ambient concentrations. Since the VALLEY model is well documented (EPA 1977), only the departures of the sequential model from the established VALLEY algorithms are discussed in this appendix.

Sequential Hourly Calculations

The VALLEY model was modified to calculate a series of hourly average concentrations based on hourly observed meteorological conditions. Concentrations for averaging periods longer than one hour are determined by averaging consecutive hourly average values. For short-term predictions, the VALLEY model assumes a single worst-case meteorological scenario, whether or not this condition actually occurs at the locations of interest. The assumptions for predicting maximum 3-hour and 24-hour concentrations are: the worst-case 3-hour value is the same as the worst-case hourly value; and the worst-case 24-hour concentration is one-fourth the worst-case hourly value. The guideline model is capable of calculating individual hourly concentrations for specific combinations of meterorological input variables only, and long-term (e.g., annual average) concentrations by incorporating a stability wind rose.

Source Based Coordinate System

The model was modified to allow the use of a Cartesian coordinate system (see Figure A-1 from Appendix A-3). The EPA VALLEY model is restricted to a rather less flexible polar coordinate system. The sequential VALLEY modification allows concentrations to be computed at a large number of points of interest during any simulation.

Terrain Adjustment for Nonstable Conditions

Under nonstable conditions the EPA VALLEY model allows the plume centerline to remain at a constant height above the ground, thereby

simulating plume rise and dispersion as if the plume were transported over flat terrain. The effects of irregular terrain are accounted for in the sequential VALLEY model by a stability dependent adjustment of plume height relative to the underlying terrain elevation. The effective plume height, H is determined as follows:

$$H = \Delta h + h_s - h_c \qquad (9)$$
$$= h_o - h_c$$

where $h_c = (1\text{-}Ter)h_t$ if $h_o > h_t$

for neutral and unstable case

$h_c = (1\text{-}Ter)h_o$ if $h_o \leq h_t$

and Ter = terrain correction, 0.5 for neutral and unstable cases, 0.10 for stable cases

Δh is the plume rise, m

h_s is the stack height, m

h_c is the effective terrain height, m

h_o is the initial plume rise, m

h_t is the terrain height, m

H is the effective plume height, m

The simultaneous consideration of both the plume rise as a function of downwind distance and of the topography surrounding the point source provides a realistic simulation of the downwind transport of effluent released in areas characterized by irregular terrain. Under stable conditions, both the EPA VALLEY and the sequential VALLEY models assume the plume height above stack base remains constant after equilibrium height is reached, with the constraint that the plume centerline may never approach closer than 10 meters above the surface.

Wind Speed Determination

The wind speed used in the model is assumed to be representative of the conditions throughout the vertical height interval in which the plume is dispersing. The wind speed at the stack top elevation is used

as an approximation to this condition. Since the surface wind speed measurements are commonly taken at lower elevations than stack top, an adjustment is made in the model by the following power law relationship:

$$u(z) = u_o \left(\frac{z}{z_o}\right)^p \qquad (2)$$

where

u is the adjusted wind speed at stack height z

u_o is the wind speed measured at height z_o

p is the wind profile exponent

The profile exponent p is a function of stability class and has the values given in Table A-1. These are identical to the values used in the EPA CRSTER model.

TABLE A-1

WIND SPEED PROFILE EXPONENT

Stability Class	Wind Speed Profile Exponent, p
A	0.10
B	0.15
C	0.20
D	0.25
E	0.30
F	0.30

Buoyancy Enhanced Vertical Dispersion

For strongly buoyant plumes, the dominant contribution to their growth as they rise to stabilization height is often the entrainment of ambient air induced by the vertical motion of the plume relative to the ambient air. The buoyancy effect is supported by both the photographic data and the theoretical considerations on which the Briggs plume rise formulas are based. Incorporation of this "buoyant enhancement," therefore, avoids an inconsistency shared by many standard Gaussian models that use the plume rise formulas of Briggs, while retaining the estimates of vertical plume spread derived from observations of nonbuoyant releases.

The sequential VALLEY model includes this buoyant entrainment effect using the method suggested by Pasquill (1976). The plume growth due to buoyant entrainment effects is calculated as $\Delta H/3.5$, where ΔH is the plume rise. The total vertical spread of the plume is then calculated as:

$$\sigma_z' = \left[\left(\frac{H}{3.5}\right)^2 + \sigma_z^{\ 2} \right]^{1/2}$$

where

σ_z' is the modified vertical dispersion parameter, and

σ_z is the standard vertical dispersion parameter

Pollutant concentrations estimated by the Gaussian plume equation used in the model are inversely proportional to average wind speed. This relationship implies that concentrations will approach infinity as the wind speed approaches zero, which is clearly not the case. For this reason, hourly wind speeds that are below 1.0 m/sec are increased to 1.0 m/sec to preclude an invalid application of the model. For calm conditions when there is no measured wind direction, the wind direction from the previous noncalm hour persists. This assumption can cause the model to overestimate pollutant concentrations for multiple-hour averaging times if calms persist for several hours.

REFERENCES

EPA 1977. VALLEY Model User's Guide. EPA-450/2-77-018, September.

Pasquill, F. 1976. Atmospheric Dispersion Parameters in Gaussian Plume Modeling, Part II, Possible Requirements for Change in the Turner Workbook Values. Document 600/4-76-0306. U.S. Environmental Protection Agency.

APPENDIX A-2

DESCRIPTION OF THE MPSDM MODEL

1.1 Model Description

The Multiple Point Source Diffusion Model, MPSDM, is a flexible point source diffusion model for examination of the air quality effects of one or more sources. A sequence of hourly ground-level concentrations at downwind receptor locations is computed for a simulation period of any length. Concentrations for multiple-hour averaging times are computed from consecutive hourly values. Hourly meteorological input data include hourly surface wind direction, wind speed, stability and mixing heights as determined from vertical temperature soundings and surface winds and temperatures.

The fundamental formula used in the model is the Gaussian plume equation, used to estimate ground-level pollutant concentrations from a point source as presented in the Workbook of Atmospheric Dispersion Estimates (Turner 1969). The general form of the equation for the coordinate system (see Figure A-1 of Appendix A-3) is:

$$\chi(0,0z) = \frac{q(x, -y, H)}{2\pi\,\sigma_y\,\sigma_z u} \exp - \frac{1}{2} \frac{y}{\sigma_y}^{2} \cdot \left\{ \exp\left[- \frac{1}{2} \left(\frac{z - H}{\sigma_z} \right)^2 \right] + \exp\left[- \left(\frac{z + H}{\sigma_z} \right)^2 \right] \right\} \qquad (1)$$

where

(x,y,z) are the (upwind, cross-wind, and vertical) components of a Cartesian coordinate system, such that the receptor point is located at or vertically above the origin (expressed in units of length) and the source is at the point $(x, -y, H)$;

$\chi(0,0,z)$ is the pollutant concentration at receptor location $(0,0,z)$ (mass/length^3);

H is the effective height (stack height plus plume rise) of emission, that is the centerline height of the plume (length);

q is the source strength (mass/time);

σ_y, σ_z are dispersion coefficients that are measures of cross-wind and vertical plume spread. These two parameters are functions of downwind distance and atmospheric stability (length); and

u is average wind speed (length/time).

The wind speed used in the model is assumed to be representative of the conditions throughout the vertical height interval in which the plume is dispersing. The wind speed at the stack top elevation is used as an approximation to this condition. Since the surface wind speed measurements are commonly taken at lower elevations than stack top, an adjustment is made in the model by the following power law relationship:

$$u(z) = u_o \left(\frac{z}{z_o}\right)^p \qquad (2)$$

where

u is the adjusted wind speed at stack height z

u_o is the wind speed measured at height z_o

p is the wind profile exponent

The profile exponent p is a function of stability class and has the values given in Table A-1. These are identical to the values used in the EPA CRSTER model.

The source base is at $z = 0$ in the coordinate system. The most important assumptions on which the Gaussian plume formula is based are the following:

1) The mean stack-top wind speed and direction are uniform in space and constant throughout the period of each concentration calculation, typically one hour.

2) When the effluent plume enters the atmosphere, it rises until it reaches an equilibrium altitude H.

TABLE A-1

WIND SPEED PROFILE EXPONENT

Stability Class	Wind Speed Profile Exponent, p
A	0.10
B	0.15
C	0.20
D	0.25
E	0.30
F	0.30

3) At any downwind distance, the maximum concentration occurs at the plume centerline. The distribution of concentration values off the centerline is given by the product of two Gaussian distributions, one in the y-direction (crosswind) and one in the z-direction (vertical).

4) The concentration profiles described by the Gaussian form are not "instantaneous" plume profiles. Instead they represent concentrations averaged over some time period (1-hour). Consequently, they incorporate the normal variability of wind flow for this time period.

5) All material in the plume is reflected by the ground. This assumption is the basis for the second exponential term in z (Equation 1). Depletion of plume mass by deposition or chemical reaction can be approximated by an exponential decay term if desired.

6) The effluent rate and the meteorological parameters determining plume geometry are constant during the period of interest (that is, the equation represents steady state conditions).

Specification of Meteorological Inputs

Calculations performed with MPSDM involve multiple applications and spatially integrated forms of the Gaussian plume equation for all source-receptor pairs. Exact wind speeds and wind directions from a representative measurement site are input for each hour of the simulation period. Atmospheric stability category, as determined from the available data (e.g., cloud cover and wind speed, wind direction variability or vertical temperature difference and wind speed) is also input directly for each hour.

Because upper air measurements are routinely taken only twice per day (near 0000 and 1200 GMT), it is necessary to incorporate an interpolation scheme to estimate mixing depths for each hour of the day. In The Benkley-Schulman mixing depth scheme (Benkley and Schulman 1979) was employed to calculate hourly mixing depths (See Appendix A-5 for a discussion of the Benkley-Schulman Mixing Depth Scheme).

Calculation of Ground-Level Concentrations

Hourly ground-level pollutant concentrations for unlimited mixing conditions can be obtained by setting z = 0 in Equation 1. The resulting equation is:

$$\chi(0,0,H) = \frac{q}{\pi \sigma_y \sigma_z} \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \qquad (4)$$

Horizontal and vertical dispersion coefficients (σ_y, σ_z) for each of five stability categories are expressed in the form ax^b, as determined by fitting the curves in Figures 3-2 and 3-3 of Turner's Workbook. Table A-2 presents the constants a and b (Texas Air Control Board 1979).

Horizontal Dispersion Under Stable Conditions

In order to account for the effects of increased horizontal dispersion under stable conditions in irregular terrain, the Gaussian distribution in the horizontal represented by

$$\frac{1}{\sqrt{2\pi}\sigma_y} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right]$$

is replaced in the model with a uniform 22.5° distribution function, defined by the formula:

$$\frac{1}{C} \quad \text{for} \quad |y| \leq \frac{C}{2}$$

$$0 \quad \text{for} \quad |y| > \frac{C}{2}$$

where $C = 2x \tan(11.25°) = 0.398\ x$

x = downwind distance

Buoyancy Enhanced Vertical Dispersion

For strongly buoyant plumes, the dominant contribution to their growth as they rise to stabilization height is often the entrainment of ambient air induced by the vertical motion of the plume relative to the ambient air. The buoyancy effect is supported by both the photo-

TABLE A-2

HORIZONTAL AND VERTICAL DISPERSION COEFFICIENTS

σ_y

Stability	a_1	b_1	a_2	b_2
A-1	0.495	0.873	0.606	0.851
B-2	0.310	0.897	0.523	0.840
C-3	0.197	0.908	0.285	0.867
D-4	0.122	0.916	0.193	0.865
F-5	0.0625	0.911	0.080	0.884

σ_z

Stability	a_1	b_1	a_2	b_2	a_3	b_3
A	0.0383	1.281	0.0002539	2.089	0.0002539	2.089
B	0.1393	0.9467	0.04936	1.114	0.04936	1.114
C	0.1120	0.9100	0.1014	0.926	0.1154	0.9109
D	0.0856	0.8650	0.2591	0.6869	0.7368	0.5642
F	0.05645	0.8050	0.1930	0.6072	1.505	0.3662

For σ_y: a_1, b_1 $\quad 0.1 \text{ km} \leq x < 10.0 \text{ km}$

a_2, b_2 $\quad x \geq 10.0 \text{ km}$

For σ_z: a_1, b_1 $\quad 0.1 \text{ km} \leq x \leq 0.5 \text{ km}$

a_2, b_2 $\quad 0.5 \text{ km} \leq x \leq 5 \text{ km}$

a_3, b_3 $\quad 5 \text{ km} \leq x \leq 20 \text{ km}$

graphic data and the theoretical considerations on which the Briggs plume rise formulas are based. Incorporation of this "buoyant enhancement," therefore, avoids an inconsistency shared by many standard Gaussian models that use the plume rise formulas of Briggs, while retaining the estimates of vertical plume spread derived from observations of non-buoyant releases.

MPSDM includes this buoyant entrainment effect using the method suggested by Pasquill (1976). The plume growth due to buoyant entrainment effects is calculated as $\Delta H/3.5$, where ΔH is the plume rise. The total vertical spread of the plume is then calculated as:

$$\sigma_z' = \left[\left(\frac{H}{3.5}\right)^2 + \sigma_z^{\ 2}\right]^{1/2}$$

where

σ_z' is the modified vertical dispersion parameter, and

σ_z is the standard vertical dispersion parameter

Pollutant concentrations estimated by the Gaussian plume equation used in the model are inversely proportional to average wind speed. This relationship implies that concentrations will approach infinity as the wind speed approaches zero, which is clearly not the case. For this reason, hourly wind speeds that are below 1.0 m/sec are increased to 1.0 m/sec to preclude an invalid application of the model. For calm conditions when there is no measured wind direction, the wind direction from the previous noncalm hour persists. This assumption can cause the model to overestimate pollutant concentrations for multiple-hour averaging times if calms persist for several hours.

Plume Rise

MPSDM uses the most recent Briggs' plume rise equations (Briggs 1970, 1973, 1975). Both transitional and equilibrium plume rise values are calculated. For unstable and neutral conditions (Stability Classes A, B, C, and D), plume rise above stack top is computed by:

$$\Delta h = \frac{1.6F^{1/3}\, x^{2/3}}{u}, \qquad x < 3.5x^*$$

$$\Delta h = \frac{1.6F^{1/3}(3.5\, x^*)^{2/3}}{u}, \qquad x \geq 3.5x^* \qquad (6)$$

where

F is the buoyancy flux of stack emissions (m^4/sec^3)

x* is the downwind distance at which atmospheric turbulence dominates entrainment in plume rise (m), given by,

$$x^* = 34.49\, F^{2/5}, \qquad F > 55\ m^4/sec^3$$

$$x^* = 14.\ F^{5/8}, \qquad F \leq 55\ m^4/sec^3$$

3.5x* is the approximate downwind distance at which the plume becomes level (m)

For stable conditions (Stability Class F):

$$\Delta h = \frac{1.6F^{1/3}\, x^{2/3}}{u}, \qquad x < 2.4\ u\ S^{1/2}$$

$$\Delta h = 2.4\left(\frac{F}{uS}\right)^{1/3}, \qquad x \geq 2.4\ u\ S^{1/2} \qquad (7)$$

where

S is the stability parameter based on atmospheric lapse rate

$$S = \frac{\partial\theta}{\partial Z}\ \frac{g}{T_a}$$

and

$\partial\theta/\partial Z$ is the rate of change of potential temperature with height

g is the acceleration due to gravity, and

T_a is the ambient temperature

The equation for plume rise in a calm atmosphere, defined by winds less 3.1 mph, is as follows:

$$\Delta h = 5.0F^{1/4} S^{-3/8} \quad (8)$$

The Effects of Terrain

The effects of irregular terrain are accounted for in the model by a stability dependent adjustment of plume height relative to the underlying terrain elevation. The effective plume height, H is determined as follows:

$$H = \Delta h + h_s - h_c \quad (9)$$

$$= h_o - h_c$$

where $h_c = (1\text{-Ter})h_t$ if $h_o > h_t$

for neutral and unstable case

$h_c = (1\text{-Ter})h_o$ if $h_o \leq h_t$

and Ter = terrain correction, 0.5 for neutral & unstable cases, 0.10 for stable cases

Δh is the plume rise, m

h_s is the stack height, m

h_c is the effective terrain height, m

h_o is the initial plume rise, m

h_t is the terrain height, m

H is the effective plume height, m

The simultaneous consideration of both the plume rise as a function of downwind distance and of the topography surrounding the point source provides a realistic simulation of the downwind transport of effluent released in areas characterized by irregular terrain.

Restricted Dispersion

Turbulent mixing and vertical diffusion of a plume may be limited by the existence of a stable layer of air aloft, i.e., an inversion

layer. The effects of limited mixing (or plume "trapping") on plume dispersion are incorporated into the MPSDM model by the assumption that the plume is completely reflected at the mixing height, as well as at the ground. Trapping is simulated using the classical trapping model presented in the Turner Workbook, Equation 5.8, page 36, (Turner 1969). In this procedure, each reflection is represented by an "image plume" from an imaginary source with a "stack height" equal to the vertical distance travelled by the plume "edge" to the point of ground reflection. This procedure is used whenever the plume centerline is calculated to be less than 50 meters above the base of the elevated stable layer.

Stack Downwash

Briggs (1970) and Gifford (1972) stated that if the stack exit velocity is not at least 1.5 times greater than the mean wind speed, aerodynamic turbulence created by the stack itself could retard normal plume rise and contribute to high ground-level concentrations. Therefore, if a stack's effluent exit velocity is known, a critical wind speed, u_c, which can potentially initiate the downwash phenomenon can be evaluated as follows:

$$u_c = v_e/1.5$$

where v_e is the stack exit velocity and u_c is the critical wind speed. Downwash is simulated in the model for a given stack when the enviromental wind speed is greater than the calculated critical value for the stack.

In downwash, the plume rise (effective stack height, h') under stack downwash conditions becomes:

$$h' = h_s + 2D\left[\frac{V_e}{u} - 1.5\right] + \frac{8D\left[2\left(1.5 - \frac{V_e}{u}\right)\right]^{1/2}}{\pi} \qquad (10)$$

where h_s is the stack height and D is the inside stack diameter. The term on the far right makes the MPSDM model slightly more conservative than Briggs (1975) in simulating stack-tip downwash effects. The term is based on Briggs' assumption that the plume rise is equivalent to plume depth at any given downwind distance. Therefore, plume rise is directly related to plume cross-sectional area.

Background Concentration Levels

MPSDM incorporates the option to allow the use of air quality measurement data to identify background ambient levels. In this context the term 'background' applies to the contribution of sources other than those explicitly included in the diffusion calculations. If air quality measurement data are available, the hourly concentration values at all monitoring sites are input directly with the concurrent meteorological information. For each hour of the simulation, the average of the concentration values measured at monitors outside the influence of the point source plumes is computed and added to the contributions of the modeled sources at all receptors. A geometric criterion is used to determine background monitoring sites. These stations are defined as those more than 60° from the plume centerline trajectory as defined by the mean wind.

REFERENCES

Benkley, C.W. and L.L. Schulman 1979. Estimating Hourly Mixing Depths from Historical Meteorological Data. J. of Appl. Meteor., 18, pp. 772-780.

Briggs, G.S. 1970. Some Recent Analyses of Plume Rise Observation, Second International Clean Air Congress of the International Union of Air Pollution Prevention Association, Washington, DC.

Briggs, G.A. 1973. Diffusion Estimation for Small Emissions. Air Resources Atmospheric Turbulence and Diffusion Laboratory, 1973 Annual Report. ATDL-106, National Oceanic and Atmospheric Administration, Oak Ridge, TN.

Briggs, G.A. 1975. Plume Rise Predictions, Lectures on Air Pollution and Environmental Impact Analyses. American Meteorological Society Workshop, September 29 through October 3, 1975, Boston, MA.

Gifford, F.A., Jr. 1972. Atmospheric Transport and Dispersion Over Cities, Nuclear Safety 13(5), pp. 391-401.

Pasquill, F. 1976. Atmospheric Dispersion Parameters in Gaussian Plume Modeling, Part II, Possible Requirements for Change in the Turner Workbook Values. Document 600/4-76-0306. U.S. Environmental Protection Agency.

Texas Air Control Board 1979. Users Guide to the Texas Episodic Model Version 8. October.

Turner, D.B. 1969. Workbook of Atmospheric Dispersion Estimates, U.S. Department HEW, Public Health Service, NAPCA, Cincinnati, OH.

APPENDIX A-3

THE MINE MODEL

APPENDIX A-3

THE MINE MODEL

The ERT MINE model was developed specifically for the air quality analysis of typical mining operations and their associated fugitive dust emissions. MINE is a Gaussian model that allows the examination of multiple sources as well as multiple meteorological conditions. It can compute average concentrations for time periods extending from an hour to a year. The capability of simulating particle deposition is a special feature of MINE and was developed exclusively for the treatment of fugitive dust sources.

The MINE model itself consists of three self-contained program units:

- MINE which calculates concentrations at each receptor for 480 distinct meteorological conditions and 5 particle size distribution classes, and
- MESHER and ANNUAL which combine the meteorological specific concentrations calculated by MINE with either sequential hourly data (MESHER) or an annual wind rose (ANNUAL) to produce concentrations representative of a specific period or set of conditions.

A.1 Overview

The MINE model has the following features.

<u>Receptors</u>

Concentrations are calculated for up to 128 receptors at arbitrary locations. The receptor coordinates may be input in user-defined units. Background concentrations and calibration factors may be specified for each receptor.

Sources

This model treats three types of sources: areas, lines, and points. In the case of a point source, a steady-state emission rate (in g/sec) is assumed for a single point of zero extent. This point may be elevated to take into account the height of a stack. In the case of a line source, a straight line segment at constant height is assumed. The coordinates of the end points define the segment. The emission rate for a line source is specified as a mean density, i.e., in g/sec/m. In the case of an area source, a rectangular region with axes oriented east-west and north-south is assumed. The region is assumed to be at constant height, and emissions for the source are distributed as a mean area density, i.e., in g/m^2-sec. For the case when deposition is being used, and actual emission rate may be a function of wind speed, up to five emission factors for five different particle size classes may be input.

Meteorological Classes

MINE uses five stability classes, corresponding to Turner's classification, with all stable classes treated as one. Up to 16 wind direction classes can be considered with the default yielding the directions of the 16-point compass. Up to six wind speed classes are considered with default values corresponding to NWS categories. The model uses one mixing height for each stability class.

Horizontal Dispersion

MINE uses a uniform 22.5 degree crosswind distribution to simulate plume dispersion in the horizontal or crosswind direction. In this situation, the horizontal Gaussian distribution is replaced uniformly by the average concentration across the wind sector.

Vertical Dispersion

To simulate trapping, MINE computes vertical dispersion using a Gaussian plume reflected both from the ground and the mixing lid, as in Turner's workbook (1970).

Deposition

Deposition is treated in MINE by dividing the total emissions from a near ground-level source of particulates into emissions from five particle-size categories. Each category has a particular settling velocity, v_d and a specific gravitational settling velocity, v_g. The ratio of apparent emission rate at distance x downwind (Q_x) to the initial emission rate (Q_o) is determined by the equation of Ermak (1977). A more detailed discussion is contained in the technical description which follows.

A.2 Technical Description

A.2.1 MINE

The fundamental formula used in MINE is the Gaussian plume equation which, as presented in the Workbook of Atmospheric Dispersion Estimates (Turner 1970), estimates pollutant concentrations from a point source. The general form of the equation for the coordinate system presented in Figure A-1 is:

$$\chi(0,0,z) = \frac{q(x,-y,H)}{2\pi\,\sigma_y\,\sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \cdot \left\{\exp\left[-\frac{1}{2}\left(\frac{z-H}{\sigma_z}\right)^2\right] + \exp\left[-\frac{1}{2}\left(\frac{z+H}{\sigma_z}\right)^2\right]\right\} \qquad (1)$$

where

(x,y,z) are the (upwind, cross-wind, and vertical) components of a Cartesian coordinate system, such that the receptor point is located at or vertically above the origin (expressed in units of length) and the source at the point (x,-y,H),

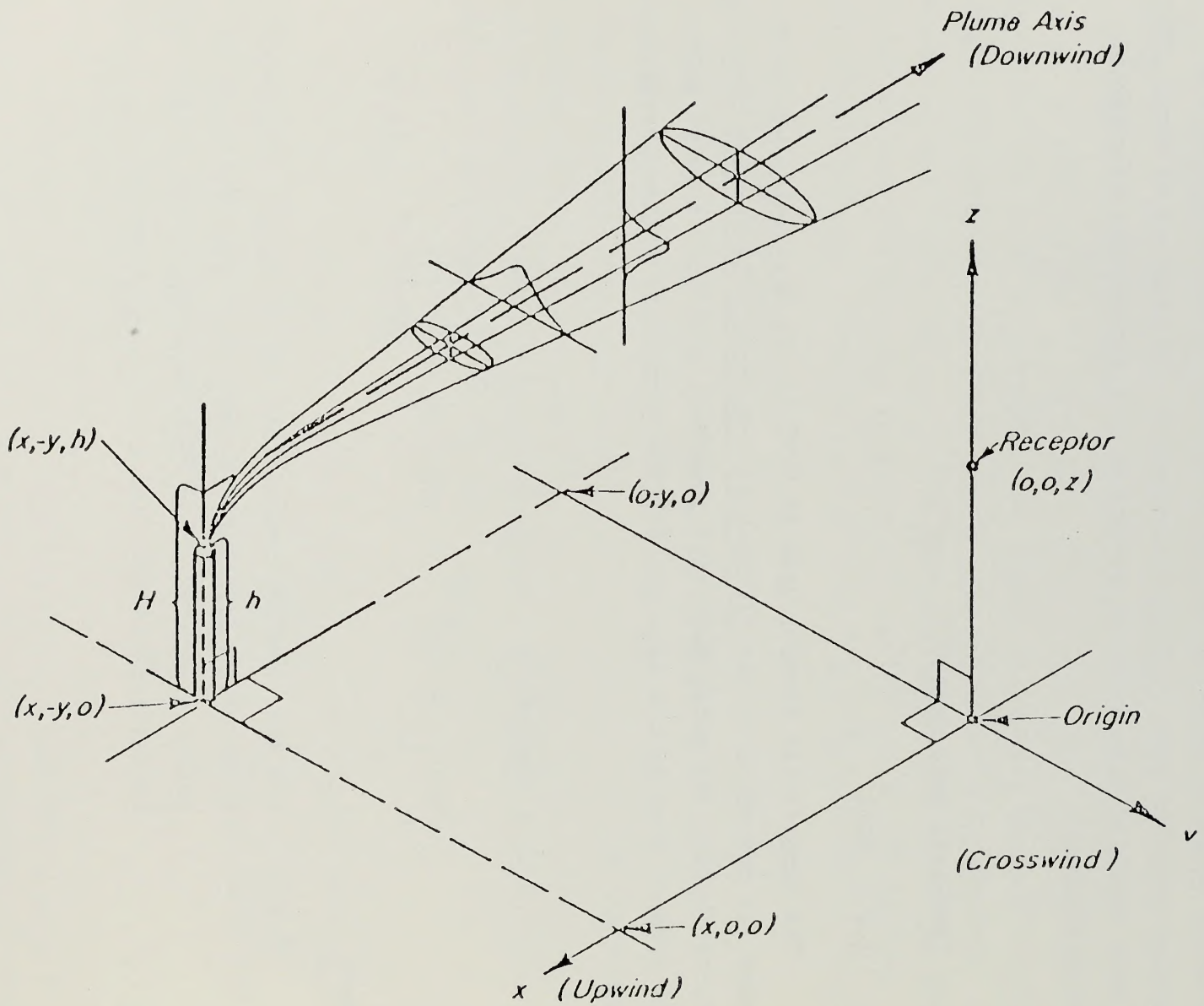


Figure A-1. Coordinate system used in Gaussian diffusion equation.

$\chi(0,0,z)$ is the ground-level pollutant concentration from a point source at a receptor (0,0,z) (mass/length^3),

H is the effective height (stack height plus plume rise) of emission and, therefore, the centerline height of the plume (length),

q is the source strength (mass/time),

σ_y, σ_z are dispersion coefficients that are measures of cross-wind and vertical plume spread which are functions of downwind distance and atmospheric stability (length), and

u is average wind speed (length/time).

The dispersion conditions represented by the Gaussian plume equation are steady-state; that is, the emission rate and the meteorological parameters determining plume geometry are constant throughout the period of interest.

In general, mining operations feature emission sources near ground level. As the pollutant is diffused downwind, the plume centerline (the level of maximum concentration) will remain at ground level. MINE, however, does not take into account the effects of terrain on effluent dispersion. Ground-level concentrations are calculated as if over a flat surface (z=0) using the modified equation:

$$\chi(0,0,0) = \frac{q(x,-y,0)}{2\pi\sigma_y\sigma_z u} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \cdot 2\,2\left\{\exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]\right\} \qquad (2)$$

Emission Rates

In MINE, the pollutant emissions can be made a function of wind speed to simulate the effect of wind action on dry, soil materials. The emission rate $q(x,-y,0)$ can be defined as a function of some power of the wind speed as follows:

$$q(x,-y,0) = Q\,u^s$$

where

Q is the pollutant emission factor,

u is the wind speed (m/sec), and

s is the exponent of the wind speed.

An exponent of one would represent a linear dependence on wind speed; an exponent of two would represent a quadratic dependence on wind speed; and so on. An exponent of zero would remove from the emissions all dependence on wind speed.

Horizontal Distribution Function

For point, line, and area sources, the horizontal distribution is defined as a function of c, the half-width of the appropriate sector at distance x downwind of the source.

$$c = x \tan \frac{\theta}{2} \tag{3}$$

where

c is the half-width of sector (m)

x is the downwind distance (m)

θ is the sector angle (22.5°).

The horizontal distribution function is defined by the formula:

$$hdf(x,y) = \begin{cases} \frac{1}{2c} & |y| \leq c \\ 0 & |y| \geq c \end{cases} \tag{4}$$

where

c is 0.1989x.

The equation used to calculate hourly pollutant concentrations is then given by:

$$\chi(0,0,0) = \frac{q(x,-y,0)}{\sqrt{2\pi}\,\sigma_z u}\ hdf\ (x,y)\ \cdot$$

$$2\left\{\exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]\right\} \qquad (5)$$

Vertical Distribution Function

The vertical distribution function used by MINE is the well-known Gaussian distribution, adjusted to include perfect reflection off the ground surface at z = 0 and the mixing lid. The vertical distribution function used in MINE is:

$$vdf(x,0,H) = \begin{cases} F_z(x,0,H) & \text{if } x \leq x_T \\ \left(2 - \frac{x}{x_T}\right) \cdot F_z\ (x,0,H) + \left(\frac{x}{x_T} - 1\right)\frac{1}{DM} & \text{if } x_T \leq x \leq 2x_T \\ \frac{1}{DM} & \text{if } x > 2x_T \end{cases} \qquad (6)$$

where

$F_z(x,0,H)$ is the reflected Gaussian for ground-level concentrations

$$F_z(x,0,H) = \frac{2}{\sqrt{2\pi}\,\sigma_z}\left\{\exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]\right. \qquad (7)$$

DM is the mixing depth (m);

σ_z is the vertical dispersion coefficient (m); and

x_T is the trapping distance (m).

The trapping distance is defined as that distance from the source at which σ_z = 0.47 DM.

Equation (2) becomes

$$\chi(0,0,0) = \frac{q(x,-y,H)}{u} \; hdf\,(x,y) \cdot vdf\,(x,0,H) \tag{8}$$

The vertical dispersion σ_z is calculated by the formula:

$$\sigma_z = ax^b + c + d. \tag{9}$$

Default values of a, b, and c are given in Table A-1. The parameter, d, represents an initial mixing dimension, which simulates the local mechanical turbulence caused by equipment activity. For example, this could represent the "puff" of dust emitted into the atmosphere during the operation of earth-handling equipment or during the movement of vehicles along a dirt road.

Treatment of Area Sources

The contribution from an area source is obtained by integrating Equation 8 over the area:

$$\frac{\chi u}{Q} = \iint_A hdf(x,y)\; vdf(x,z,H)\; dx\, dy \tag{10}$$

Since only the horizontal diffusion term depends on y, and since the integral of hdf(x,y) over y can be analytically evaluated, the double integral reduces to a single integral.

$$\frac{\chi u}{Q} = \int_{x1}^{x2} hdfI(x)\; vdf(x,z,H)\; dx \tag{11}$$

where $$hdfI(x) = \int_{y_{min}}^{y_{max}} hdf(x,y)\; dy$$

The single integral is then evaluated by dividing the area into a number of vertical strips (see Figure A-2).

The area source integration then involves the summation of contributions from each elemental area and the total concentration at a receptor due to an area source is given by:

TABLE A-1

VERTICAL DISPERSION COEFFICIENTS

Coefficient	Stability Class 1	2	3	4	5
	Range 1 ($0 < x < 100$ m)				
a	0.174	0.143	0.123	0.080	0.060
b	0.936	0.922	0.905	0.881	0.845
c	0.0	0.0	0.0	0.0	0.0
	Range 2 ($100 \leq x < 1{,}000$ m)				
a	0.001	0.048	0.119	0.187	0.135
b	1.890	1.110	0.915	0.755	0.745
c	9.600	2.000	0.0	-1.400	-1.100
	Range 3 ($1{,}000 \leq x < 50{,}000$ m)				
a	0.001	0.048	0.119	2.610	52.600
b	1.890	1.110	0.915	0.450	0.150
c	9.600	2.000	0.0	-25.500	-126.000

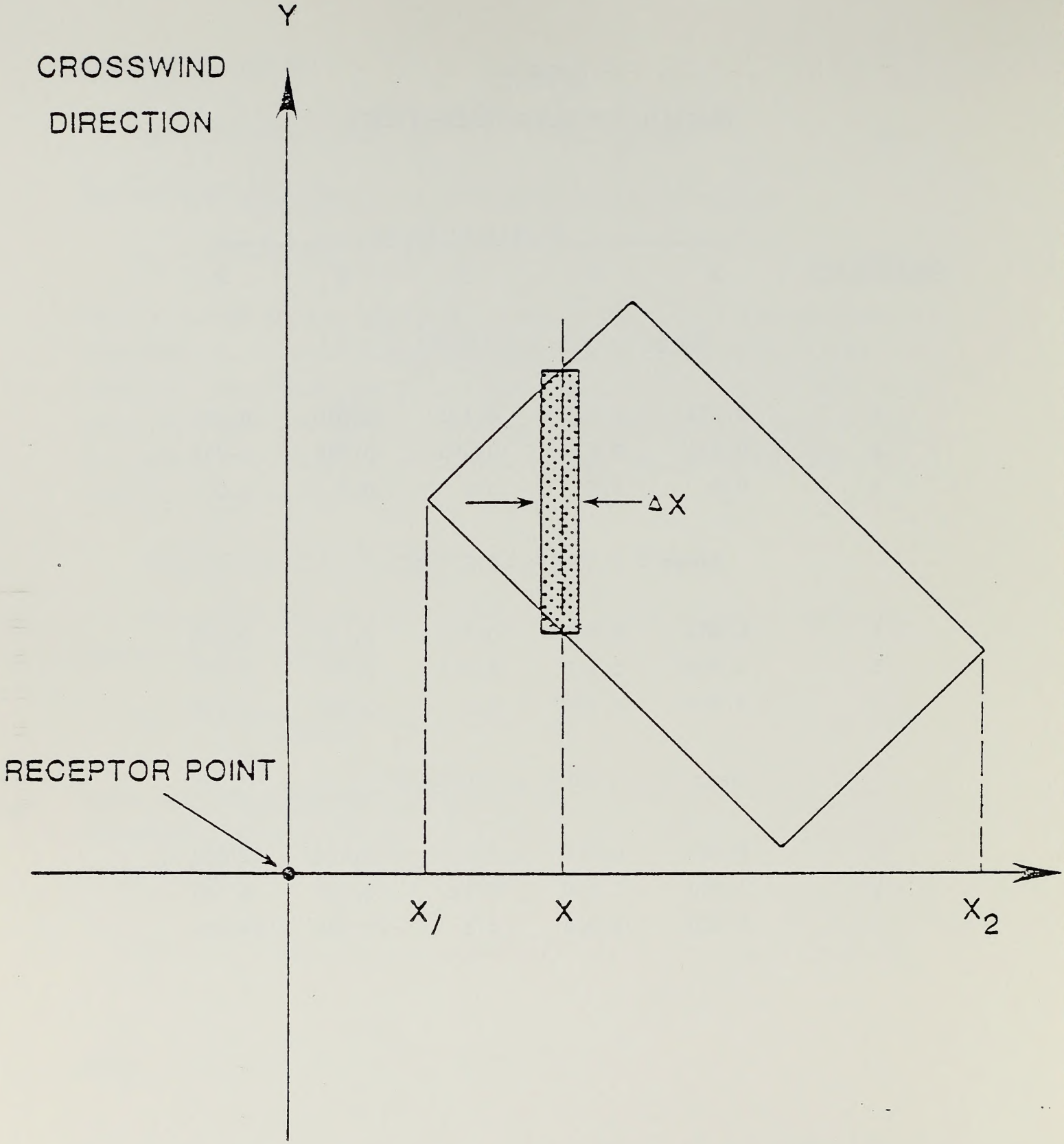


Figure A-2. Integration Over Source Cell Area by Summation of Elemental Areas.

$$\frac{\chi u}{Q} = \sum_{i=1}^{M} [hdfI(x_i)\ vdf(x_i,z,H)] \cdot \frac{DX}{M} \tag{12}$$

where

x_i is the value at x at center of strip i.

Treatment of Line Sources

The contribution from a line source is calculated by integrating Equation 8 over the line source.

$$\frac{\chi u}{Q} = \int_L hdf(x,y)\ vdf(x,z,H)\ dl \tag{13}$$

The line source is first intersected by a 22.5° sector oriented with its vertex on the receptor and opening upwind. Only that portion of the line source within the sector is used in the computations (see Figure A-3a).

The resulting line segment is divided into a specified number of pieces for numerically approximating the integral. Each piece is treated as a point source (see Figure A-3b). The sector half-width used in the horizontal distribution function is then defined by:

$$c = x_i \tan\frac{\theta}{2} + \frac{dy}{2} \tag{14}$$

where

x_i is the x-coordinate of center of line segment piece i relative to receptor and wind direction

θ is the sector angle

dy is the y-extent of a line segment piece.

The total concentration at a receptor due to a line source is given by the sum over the line segment pieces.

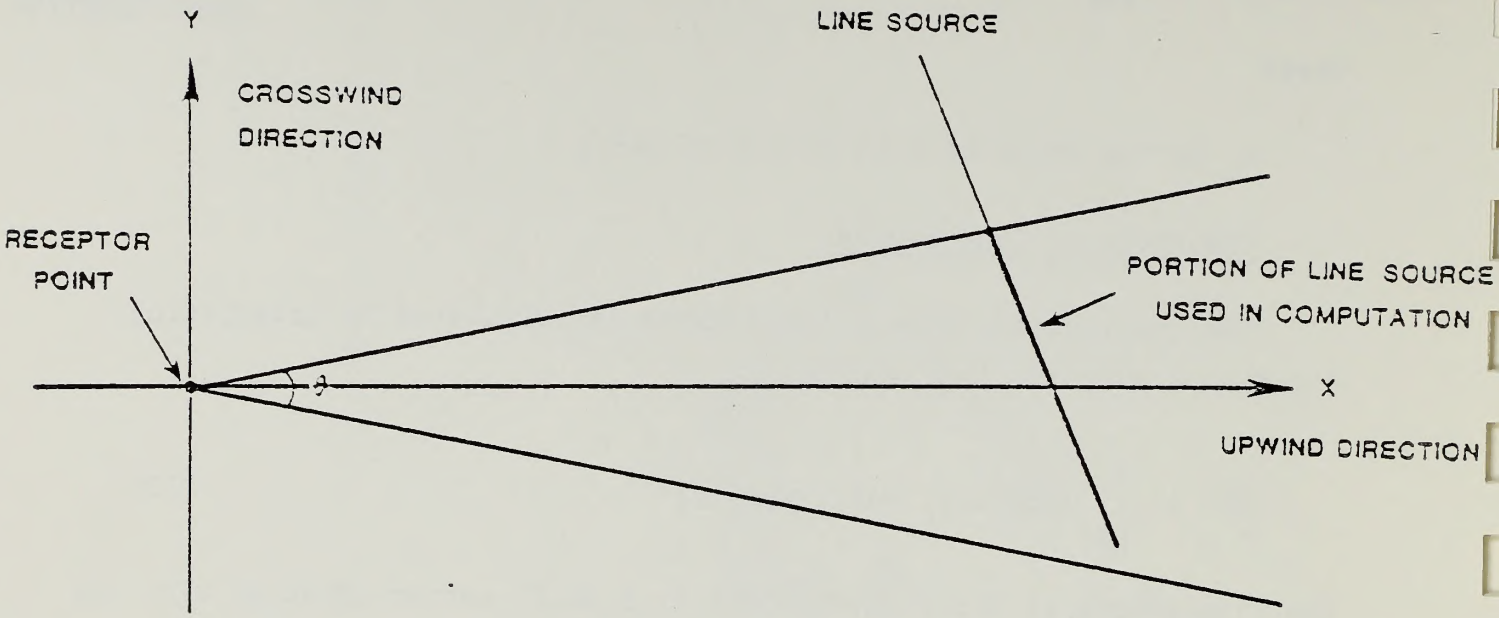


Figure A-3a. Determination of portion of line source within averaging section.

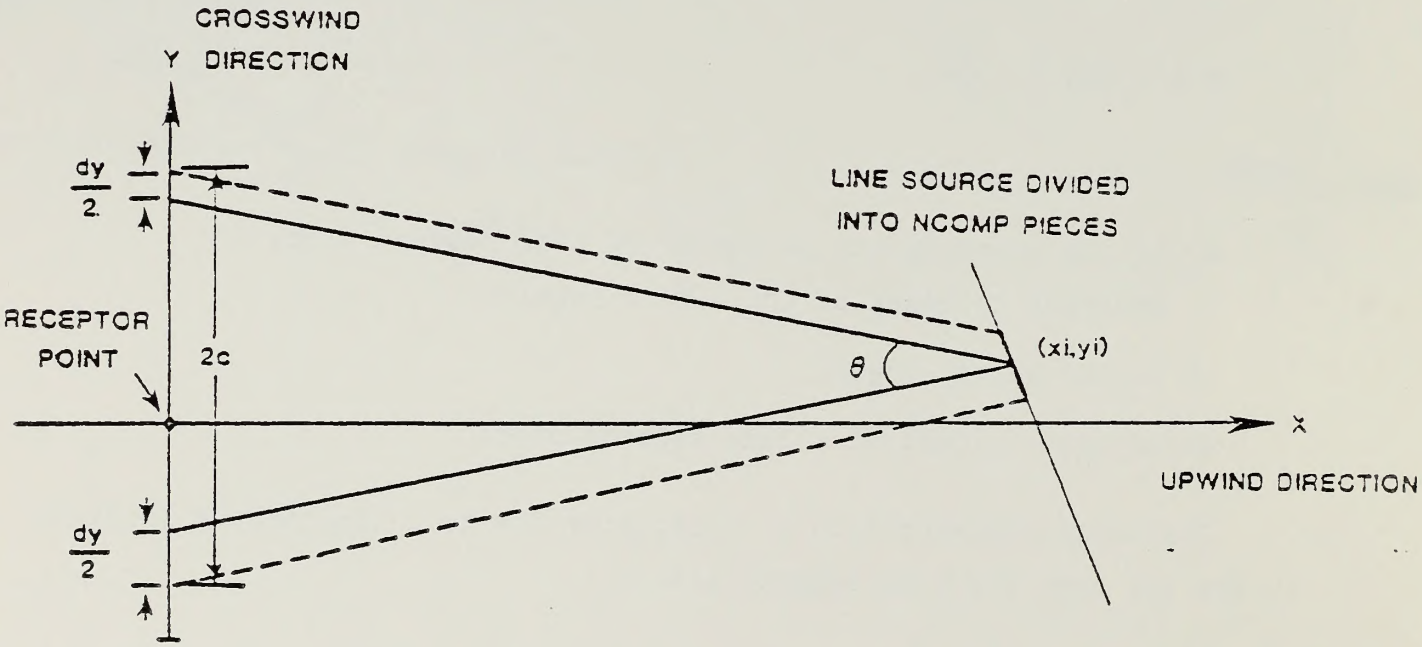


Figure A-3b. Integration over line source by summation of finite number of line segments.

Particle Deposition

In MINE, the Ermak deposition function is used to account for gravitational settling and fallout of suspended particles. MINE handles deposition by considering the total particulate emissions as being made up of five particle-size classes. Each particle size settles at a different gravitational rate, v_g and a different deposition rate, v_d, and therefore the distribution of particle sizes in the plume changes as distance from the source increases.

The Ermak equation as used here corrects the typographical errors which were in the Ermak (1977) publication. The Ermak equation has the form:

$$\chi = \frac{Q}{\pi \sigma_y \sigma_z u} \exp\left(-\frac{1}{2}\frac{y^2}{\sigma_y^2}\right) \exp\left(-\frac{V_g z}{2K} - \frac{V_g^2 \sigma_z^2}{8K^2}\right)$$

$$\times \left[\exp\left(-\frac{1}{2}\frac{z^2}{\sigma_z^2}\right) - \left(\frac{\pi}{2}\right)^{1/2} \frac{V_1 \sigma_z}{K} \exp\left(\frac{V_1 z}{K} + \frac{V_1^2 \sigma_z^2}{2K^2}\right)\right.$$

$$\left. \times \operatorname{erfc}\left(\frac{V_1 \sigma_z}{2^{1/2} K} + \frac{z}{2^{1/2} \sigma_z}\right)\right] \quad \text{where}$$

χ = Concentration of pollutant (g/m^3)

Q = Emission rate (g/sec)

σ_y = Horizontal dispersion coefficient (m)

σ_z = Vertical dispersion coefficient (m)

u = Wind speed (m/sec)

(x,y,z) = Distance as measured from source (m)

a,b = Deposition parameters, functions of stability (dimensionless)

U_d = Deposition velocity (m/sec)

K = Eddy diffusity (m^2/sec)

V_g = Gravitational settling velocity (m/sec)

V_1 = $U_d - V_g$ (m/sec)

The term "erfc" is the complementary error function. Ermak's equation was further reduced by letting:

$$K = \frac{\sigma_{z2u}}{2\ x}$$

as recommended by Becker and Takle (1979). By using this and setting $z = 0$, the equation was integrated in the crosswind direction for the purpose of calculating 22.5° sector average concentrations. The resultant equation is as follows:

$$\chi = \frac{Q}{\sqrt{2\pi}\ \sigma_z\ u\ x \tan(11.25^\circ)} \exp\left(-\frac{1}{2}\left(\frac{V_g\ x}{u\sigma_\equiv}\right)^2\right)\left[1 - \pi^{1/2}\ \beta \exp(\beta^2)\operatorname{erfc}(\beta)\right]$$

where: $\beta = \dfrac{V_1\ 2^{1/2}\ x}{\sigma_\equiv\ u}$.

A.2.2 MESHER

MESHER is a post-processor program used to access the hourly concentration fields calculated using MINE by "meshing" them with known hourly meteorological data. The time-specific hourly concentraton values can then be averaged over a specified period of time from one hour to a full day (24 hours).

MESHER requires a meteorological data file which tells the program which specific concentrations corresponding to the meteorology must be retrieved from the MINE output. The meteorological data file must supply for each hour desired:

- day of the year,
- hour of the day,
- wind speed classification,
- stability classification, and
- wind direction classification.

In addition, MESHER will sort the hourly concentrations so that a specified number of the highest concentrations with day and hour of occurrence can be obtained.

A.2.3 ANNUAL

To calculate annual average concentrations, meteorological data in the form of a stability wind rose is combined with the concentrations calculated by MINE. Based on hourly meteorological measurements, a stability wind rose is a statistical description of local air pollution meteorology. The wind and stability data are arranged in a joint frequency distribution of 5 stability classes, 16 wind directions, and 6 wind speeds. The 5 stability classes are those of Pasquill, ranging from very unstable to stable (Classes A through D and a combination of E and F). The 16 wind directions are the standard 16-point compass directions. The 6 wind speed classes are: 0-3 knots, 3-6 knots, 6-10 knots, 10-16 knots, 16-21 knots, and greater than 21 knots. The stability wind rose, therefore, provides the frequency of each of 480 distinct

steady-state meteorological conditions used by MINE in the calculation of concentrations.

For a specific source-receptor configuration, the annual-average concentration, $\overline{\chi}$, is obtained by summing all concentrations and weighing each one according to its frequency for the particular wind direction, wind speed class, and stability class. The average concentration is:

$$\overline{\chi} = \sum_K \sum_L \sum_J F(J,K,L) \cdot \chi(J,K.L) \tag{17}$$

where

$F(J,K,L)$ is the normal frequency during the period of interest for wind direction interval K, wind speed class J, and stability class L and

$\chi(J,K,L)$ is the average ground-level concentration.

The total concentration at a specific receptor is obtained by summing the results of equation 17 over all sources.

REFERENCES

Becker, D.L. and Takle, E.S. 1979. "Particulate Deposition from Dry Unpaved Roadways". Atmospheric Environment Vol. 13, pp. 661-668.

Ermak, D.L. 1977. "An analytical model for air pollutant transport and deposition from a point source". Atmospheric Environment Vol. 10, pp. 231-237.

Turner, D.B. 1970. "Workbook of Atmospheric Diffusion Estimates." U.S. Department of Health, Education and Welfare, Public Health Services, National Air Pollution Control Administration, Cincinnati, OH.

APPENDIX A-4

ESTIMATION OF PASQUILL STABILITY CLASSES

ESTIMATION OF PASQUILL STABILITY CLASSES

Diffusivity is highly dependent on atmospheric stability conditions which can be estimated by the Monin-Obukhov lengths. The Monin-Obukhov length is physically interpreted to be the approximate height above the surface at which buoyancy effects become comparable with shear effects, which dominate below this height. Thus, under stable conditions, this length (L) equals roughly the height at which vertical turbulence is suppressed. Under very stable conditions, L becomes small and resultant downwind air pollutant concentrations are high. When conditions are unstable, L is the physical height at which convectively produced turbulent energy compares with mechanically produced energy. Above a height equal to L, bouyancy driven convection predominates; therefore, turbulence is higher, atmospheric diffusion more efficient and downwind pollutant concentrations less. When the absolute value of L approaches infinity, neutral atmospheric conditions prevail. Since the Monin-Obukhov length is not a quantity which is routinely measured, it is typically estimated from conventional weather data.

The most common surface stability classification scheme used in air pollution meteorology was originally devised by Pasquill (1962) and later modified by Turner (1964). Pasquill categories are, essentially, a function of the radiation balance of the surface of the earth and the wind speed. Pasquill and Turner surface stabilities are generally categorized in seven classes as follows:

A = extremely unstable

B = unstable

C = slightly unstable

D = neutral

E = slightly stable

F = stable

G = very stable

Two types of measured data are used to estimate Pasquill stability classes - wind speed and temperature difference with height. For the Rio Blanco project, this estimation was based upon wind speeds recorded at a height of 60 m and temperature differences recorded at heights of 10 m and 60 m.

The temperature stratification for the surface boundary layer can be obtained from meteorological tower data using the integrated form (Benoit 1977) of the Businger-Dyer flux gradient equations (Businger et al. 1971). The equations are as follows:

Stable Temperature Stratification

$$u(z) = \frac{u_*}{k}\left[\ln(z/z_o) + \beta(z-z_o)/L\right], \quad (1a)$$

$$\Theta(z_z) - \Theta(z_1) = -\frac{H_o}{k\rho c_p u_*}\left[\alpha \ln(z_z/z_1) + \beta(z_z-z_1)/L\right] \quad (1^b)$$

and

Unstable Temperature Stratification

$$u(z) = \frac{u_*}{k}\left\{\ln(z/z_o) + \left[\ln\frac{(\zeta_o^2+1)(\zeta_o+1)^2}{(\zeta^2+1)(\zeta+0^2)}\right] + 2\left[\tan^{-1}(\zeta) - \tan^{-1}(\zeta_o)\right]\right\} \quad (2a)$$

$$\Theta(z_z) - \Theta(z_1) = -\frac{\alpha Ho}{k\rho c_p u_*}\left[\ln(z_2/z_1) + 2\ln\left(\frac{\zeta_1^2+1}{\zeta_2^2+1}\right)\right] \quad (2b)$$

where

L = Monin-Obukhov length

$u(z)$ = wind speed at height z

$\Theta(z)$ = potential temperature at height z

k = von Karman's Constant

u_* = friction velocity

H_o = surface flux of sensible heat

ρ = air density

Z_o = roughness height

C_p = specific heat at constant pressure

$\alpha = .74$

$\beta = 4.7$

$\int_o = (1 - \partial z./L)^{.25}$

$\int_i = (1 - \partial_1 z_i/L)^{.25}$

$\int = (1 - \partial z/L)^{.25}$

$\partial = 15$

$\partial_1 = 9$

g = gravitational acceleration

Let equations (1) and (2) be expressed as

$$u(z) = u_* F, \tag{3a}$$

$$\Theta(z_2) - \Theta(z_1) = \left(- \frac{H_o}{\rho C_p}\right) \frac{G}{u_*} \tag{3b}$$

where F and G represent terms in brackets multiplied by other terms not expressly mentioned. For unstable stratification F and G are <u>weak</u> functions of L. Thus we may take a typical value of L for unstable conditions (- 30 m) and calculate F and G for given height and separation heights of temperature sensors. We may do the same for stable stratification, taking L = + 30m, though with less accuracy since F and G vary much faster with L for stable stratification than for unstable conditions. The friction velocity may be obtained from (3a)

$$u_* = \frac{u(z)}{F}, \tag{4}$$

while from eq. (3b)

$$-\frac{H}{\rho C_p} = \left\{ \Theta\ (z_2) - \Theta\ (z_1) \right\} \frac{u_*}{G} \tag{5}$$

Substituting for u_* from eq. (4), eq. (5) takes the form

$$- \frac{H}{\rho C_p} = \left\{ \Theta\ (z_2) - \Theta\ (z_1) \right\} \frac{u\ (z)}{FG}, \tag{6}$$

The Monin-Obukhov length L is defined

$$L = - \frac{T\ u_*^3}{kg \left(\frac{H}{\rho c_p}\right)} \tag{7}$$

Substituting from equations (5) and (6), equation (7) takes the form:

$$L = \frac{T\, u^2(z)\ \ G}{F^2\ k\ g\ [\Theta(z_2) - \Theta(z_1)]} \tag{8}$$

Thus, if we assume a Kelvin temperature of 290°, we may obtain L with a knowledge of u (z) and $\Delta\Theta$. Note $L < 0$ for unstable temperature stratification and $L > 0$ for stable temperature stratification.

Golder (1970) and Myrup and Ranzieri (1976) give graphs of Pasquill stability classes as a function of surface roughness (Z_o) and 1/L. A recent study in the area (Occidental and Ashland Oil 1977) which was conducted in Tract C-b assumed a roughness factor of 7 cm. Since the vegetation and terrain roughness characteristics were observed to be similar at the Rio Blanco project site, the same roughness factor was also assumed. Using this information, the graphs of stability class as functions of $\Delta\Theta$ and u (z) were prepared. Points were plotted and isopleths drawn in the following manner.

1) For selected $\Delta\Theta$, wind speeds were obtained which mark the boundary points between Pasquill stability classes. Values of Monin-Obukhov lengths corresponding to the class boundaries were obtained for Z_o = 7 cm from the Golder (1970) and Myrup and Ranzieri (1976) graphs.

2) For $\Delta\Theta < 0$, unstable parameters F and G were used. For $\Delta\Theta > 0$ stable F and G were used.

3) Data points were plotted until a discernible isopleth was obtained.

REFERENCES

Benoit, R. 1977. On the integral of the surface layer profile-gradient functions. J. Appl. Meteor., 16, 859-860.

Businger, J.A., J.C. Wyngaard, Y. Izumi and E.F. Brandley 1971. Flux-profile relationships in the atmospheric surface layer. J. Atmos. Sci., 28, 181-189.

Golder, D.G. 1970. A comparison of stability parameters: a thesis in meteorology. Pennsylvania State University Graduate School, Department of Meteorology.

Myrup, L.O. and Ranzieri, A.J. 1976. A consistent scheme for estimating diffusivities to be used in air quality models. Prepared for California Department of Transportation, Sacramento, California.

Occidental and Ashland Oil 1977. Oil Shale Tract C-b Environmental Baseline Program Final Report Vol. 3.

Pasquill, F. 1962. Atmospheric Diffusion. D. Van Nostrand Company, Ltd., London.

Turner, B.D. 1964. A Diffusion Model for a Urban Area. J. Appl. Meteor., 3, 83-91.

APPENDIX A-5

DESCRIPTION OF THE BENKLEY-SCHULMAN MIXING DEPTH SCHEME

Benkley-Schulman Mixing Depth Scheme

This scheme distinguishes between the effects of convectively and mechanically produced turbulence for the growth and maintenance of the mixed layer. At night, only mechanical turbulence is present. The depth of the nocturnal mixed layer is usually shallow and varies only slowly with time. Although it is often stably stratified, the nocturnal layer may still be turbulent due to mechanical action of the wind shear.

During the day, solar heating and convective turbulence are normally dominant over mechanical turbulences, causing a deep afternoon mixed layer. Because the potential temperature is constant in a well mixed layer, the height of the mixed layer at any time during the day is commonly estimated on an adiabatic chart as the height of the intersection of a dry adiabat drawn from the surface temperature and the morning temperature sounding. In situations of little daytime heating or strong winds, however, the production of mechanical turbulence exceeds that of convective turbulence during the day, and the depth of the layer is more appropriately described by mechanical considerations.

The nocturnal mixing depth is shallow and varies slowly with time. After sunrise, surface heating causes the rapid growth of the convective boundary layer. The maximum depth is reached when the maximum surface temperature is reached. Once heating ceases, the mechanism for maintaining the deep layer disappears, and a new, much more weakly forced, nocturnal boundary layer reforms.

At all hours of the night, and when convective forcing is weak during the day, the mixing depth, H, is calculated from the scale height u_*/f, where u_* is the friction velocity and f, the Coriolis parameter:

$$H = c \frac{u_*}{f} \qquad (2)$$

This scaling argument has been used by many researchers. Values cited for the constant, c, range from 0.03 to 0.30. From experimental data developed for the Benkley-Schulman mixing depth scheme, a value of 0.15 for c appears to be the best approximation. Assuming a logarithmic wind profile and a roughness length of 1 m, Equation 2 becomes:

$$H \sim 150u \qquad (3)$$

where u is the wind speed in meters per second (m/sec). The wind speed used in the scheme is center-averaged for three hours around the time when mechanically driven mixing depths are computed, since the wind speed is probably subject to greater short-term variability than the mixing depth.

As an example, a 2 m/sec surface wind speed from time, t - 1 hours, to time, t + 1 hours, implies a mechanically turbulent mixing regime through a 300-meter depth at hour t.

When convective turbulence is dominant during the daytime hours, the mixing depth is defined by the uniform potential temperature method. Two simple improvements are made to the scheme, however. First, the scheme incorporates advection by a simple adjustment of surface temperatures. Second, if the 12Z temperature at the surface station differs from the 12Z surface temperature at the radiosonde station, or if the minimum relative temperature occurs after 12Z, the sounding is adjusted to account for this difference. Both modifications are explained below. Because of the standarized times of radiosonde soundings, the scheme is primarily applicable for longitudes intersecting the contiguous United States.

In some cases, strong warm or cold advection during the daytime hours significantly modifies the 12Z sounding. In these instances, hourly surface temperature alone will not reflect the actual rate at which the sun heats the mixed layer relative to the air above.

The model calls for a simple incorporation of the effects of advection, using the measured temperature change at 700 mb between 12Z and 00Z. The 700 mb mandatory level is recommended, because it is nearly always above the top of the mixed layer. (In mountainous locations, the 500 mb value may be preferable.) Use of the temperature change at 850 mb to indicate advection effects could be unrealistic due to the heating of the growing mixed layer. It is assumed that the temperature change measured at 700 mb is typical of advection throughout the lower atmosphere. During daytime hours, the model computes a relative temperature, T_r, which is the surface temperature relative to the 12Z sounding at t hours after 12Z,

$$T_r = T_m - \frac{t}{12} \left[(T_{700\ mb}\ (00Z) - T_{700\ mb}\ (12Z) \right]$$

where T_m is the measured surface temperature at t hours after 12Z. If advection is negligible, then $T_r = T_m$.

Use of T_r rather than T_m results in a more shallow estimated mixing depth during warm advection situations, and a deeper mixing depth estimation during cold advection situations. In the atmosphere, cold advection may cause the surface temperature to decrease throughout the day, despite the presence of a deep convective mixing layer, because solar heating counteracts the cold advection at the surface more effectively than at 700 mb.

At 12Z, the surface temperature at the surface station and the radiosonde station may well be different. The minimum relative temperature at the surface station may also occur before or after 12Z. The sounding should therefore be adjusted to be representative of the surface station location at the time of minimum relative temperature (the time at which the convective regime begins). This adjustment is made by modifying the sounding with a straight line from the minimum relative surface temperature (at the surface station) to the radiosonde temperature at the mechanically mixed height, H. This adjustment is realistic, because cooling of the ground surface at night effects the full nocturnal mixing layer.

At all hours during the day, the actual mixing depth assigned to a location is taken as the larger of the computed convective and mechanical mixing depths. Under clear skies, light winds and no advection, the (daytime) convective depth will be the greater of the two, while under cloudy, windy conditions, the mechanical method will produce the greater mixing depths.

For the purposes of the model, "day" and "night" are given special definitions, as follows. "Day" begins when the relative surface temperature rises one degree above the lowest relative surface temperature occurring after sunrise. It is often the case, however, that several degrees warming is necessary for the depth computed by the convective method to exceed the depth computed by the mechanical method. On rare occasions, the relative surface temperature may fall throughout the daytime hours. In these situations, the scheme remains in the nightime

regime, and a mechanical depth is computed at all hours. If the relative temperature temporarily dips for any hour before the hour of maximum temperature is reached, such as during a summer shower, the scheme remains in the daytime regime for that period and the convective depth from the previous hour persists.

"Daytime" ends when the relative temperature falls by 25% of the daytime temperature range from the relative daytime maximum. The choice of the 25% criterion is somewhat arbitrary, but some cooling must occur for the boundary layer to make the transition from daytime to nighttime conditions. The maximum afternoon depth persists during the interval between the hour of maximum T_r and the hour at which the nighttime regime begins. If, by 00Z, the relative surface temperature is still rising or has not fallen by 25% of the daytime range from the afternoon maximum, the daytime scheme continues with the 00Z to 12Z temperature advection incorporated in computing the relative surface temperature until the morning sounding.

APPENDIX A-6

DESCRIPTION OF THE AIR QUALITY MODEL PTMTP

AIR QUALITY MODEL PTMTP

This EPA dispersion model program predicts hourly concentrations at up to 30 specified receptor locations resulting from emissions of up to 25 point sources. The assumptions made in this model are:

- A Gaussian plume model is applicable to determine ground-level concentrations.
- Steady-state meteorological conditions during the hour.
- Computations can be performed according to Turner's "Workbook of Atmospheric Dispersion Estimates".
- The parameter values used for the horizontal dispersion coefficient, σ_y, and the vertical dispersion coefficient, σ_z, are those given in Figures 3-2 and 3-3 of the "Workbook".
- The sources and receptors are situated in either flat or gently rolling terrain, and the stacks are tall enough to be free from local building turbulence effects so that no aerodynamic downwash occurs.
- The wind speed and wind direction apply from the lowest to the highest plume height; no wind direction shear or wind speed shear occurs.
- The given atmospheric stability exists from ground level to well above the top of the plume.

Plume rise is calculated according to Brigg's plume rise model. For each source-receptor pair, the downwind and crosswind distances are determined. If the downwind distance is closer than the distance required for the plume to attain its final height, the plume rise for this distance is calculated. The concentration from this source at the receptor is determined by the Gaussian model using these distances.

APPENDIX B

FUGITIVE DUST CALCULATIONS

1981 OPERATIONS

CONSTRUCTION PHASE MAY 1981 THROUGH AUGUST 1981

1. TOPSOIL REMOVAL

EF = 0.38 lb/yd^3 for scrapers (PEDCo 1978)

Operational Parameter:

48,500 yd^3 removed from the pit area (PSD Source)
457,200 yd^3 removed from construction areas (Not a PSD Source)

Uncontrolled Emissions:

E = (0.38 lb/yd^3) (505,700 yd^3/4 mos) = 192,166 lb/4 mos
= 96.08 ton/4 mos. (NAAQS Source)

Short term emission rate:

$$\frac{(192{,}166 \text{ lb/4 mos.})\ (454 \text{ g/lb})}{(87 \text{ operating days/4 mos})\ (24 \text{ hr/day})(3{,}600 \text{ sec/hr})} = 11.61 \text{ g/sec} \quad \text{(NAAQS Source)}$$

Controlled Emissions:

control technique - watering
percent control - 50 percent (EPA Region VIII 1979)

(96.08 ton/4 mos) (0.5) = 48.04 ton/4 mos. (NAAQS Source)
4.61 ton/4 mos. (PSD Source)

(11.61 g/sec) (0.5) = 5.81 g/sec (NAAQS Source)
0.56 g/sec (PSD Source)

2. TOPSOIL HAUL

EF = (0.6) (0.81s) (S/30)^2 [(365-W)/365] lb/VMT (EPA 1975).
Where:
s = silt content of the haul road = 12% (gravel)
S = vehicle speed = 12 mph (scrapers)
W = number of wet days per year = 90 (PEDCo 1974)

EF = (0.6)(0.81)(12)(12/30)^2[(365-90)/365] lb/VMT = 0.703 lb/VMT

Operational Parameters:

$$\text{VMT} = \frac{(\text{total volume hauled})\ (\text{distance/trip})}{(\text{volume hauled/trip})}$$

$$\text{VMT} = \frac{(\text{volume hauled, yd}^3)\ (2 \times \text{average distance, ft.})}{(28 \text{ yd}^3\text{/trip})\ (5{,}280 \text{ ft/mi})}$$

Topsoil	Volume, yd^3	Dist, ft	VMT
Main Pit (PSD Source)	48,500	1,900	1,246.6
East Gulch (Not a PSD Source)	90,900	1,700	2,090.5
Lower Haul (Not a PSD Source)	153,200	1,700	3,523.2
Upper Haul (Not a PSD Source)	89,800	2,200	2,672.6
Shop/Office Access (Not a PSD Source)	71,000	2,100	2,017.0
Lurgi Access (Not a PSD Source)	19,300	4,300	1,122.7
Settling Pond (Not a PSD Source)	19,000	200	51.4
M.P./E.G. (Not a PSD Source)	14,000	400	75.8
TOTAL	505,700		12,800 4/mos

Uncontrolled Emissions:

E = (0.703 lb/VMT) (12,800 VMT/4 mos) = 8,998 lb/4 mos

= 4.5 ton/4 mos. (NAAQS Source)

Short term emission rate:

$$\frac{(8{,}998 \text{ lb/4 mos})(454 \text{ g/lb})}{(87 \text{ op days/4 mos})(24 \text{ hr/day})(3{,}600 \text{ sec/hr})} = 0.54 \text{ g/sec (NAAQS Source)}$$

Controlled Emissions:

control technique - watering
percent control - 50% (EPA Region VIII 1979)

(4.5 ton/4 mos) (0.5) = 2.25 ton/4 mos (NAAQS Source)
0.22 ton/4 mos (PSD Source)

(0.54 g/sec) (0.5) = 0.27 g/sec (NAAQS Source)
0.03 g/sec (PSD Source)

3. TOPSOIL DUMPING

EF = 0.03 lb/yd^3 (PEDCo 1978)

Operational Parameter:

48,500 yd^3 dumped from main pit (PSD Source)
457,200 yd^3 dumped from construction activities (Not a PSD Source)

Uncontrolled Emissions:

E = (0.03 lb/yd^3) (505,700 yd^3/4 mos) = 15,171 lb/4 mos

= 7.59 ton/4 mos. (NAAQS Source)

Short term emission rate:

$$\frac{(15{,}171 \text{ lb/4 mos})\ (454 \text{ g/lb})}{(87 \text{ op days/4 mos})(24 \text{ hrs/day})(3{,}600 \text{ sec/hr})} = 0.92 \text{ g/sec (NAAQS Source)}$$

Controlled Emissions:

control technique - watering
percent control - 50% (EPA Region VIII 1979)

(7.59 ton/4 mos) (0.5) = 3.80 ton/4 mos (NAAQS Source)
0.36 ton/4 mos (PSD Source)

(0.92 g/sec) (0.5) = 0.46 g/sec (NAAQS Source)
0.04 g/sec (PSD Source)

4. WATER TRUCK TRAFFIC

$EF = (0.6)\ (0.81s)\ (S/30)^2\ [(365-W)/365]\ \ (N/4)$ lb/VMT (EPA 1975)

s = 12% (PEDC 1974)
S = 10 mph
W = 90 wet days (PEDCo 1974)
N = number of wheels = 10

$EF = (0.6)\ (0.81)\ (12)\ (10/30)^2\ [(365-90)/365]\ (10/4)$ lb/VMT
= 1.22 lb/VMT

Operational Parameter:

VMT = (2 trucks) (10 mph/truck) (2 hrs/day) x
(87 op days/4 mos) = 3,480 VMT/4 mos

Uncontrolled Emissions:

E = (1.22 lb/VMT) (3,480 VMT/4 mos) = 4,246 lb/4 mos

= 2.12 ton/4 mos

Short term emission rate:

$$\frac{(4{,}246 \text{ lb/4 mos})\ (454 \text{ g/lb})}{(87 \text{ op days/4 mos})(24 \text{ hrs/day})(3{,}600 \text{ sec/hr})} = 0.26 \text{ g/sec}$$

Controlled Emissions:

Control technique - watering
percent control - 50% (EPA Region VIII 1979)

(2.12 ton/4 mos) (0.5) = 1.06 ton/4 mos

(0.26 g/sec) (0.5) = 0.13 g/sec

(Not a PSD Source)

5. ACCESS ROAD CONSTRUCTION

EF = 32 lb/roadgrader - hr (EPA Region VIII 1979)

Operational Parameter:

520 roadgrader hrs/4 mos

Uncontrolled Emissions:

(32 lb/roadgrader - hr) (520 roadgrader hrs/4 mos) = 16,640 $\frac{\text{lb}}{\text{4 mos}}$
= 8.32 ton/4 mos

Short term emission rate:

$$\frac{(16{,}640 \text{ lb/4 mos})\ (454 \text{ g/lb})}{(87 \text{ op days/4 mos})(2 \text{ mos const/4 mos period})(24 \text{ hr/day})(3{,}600 \text{ sec/hr})} = 2.01 \text{ g/sec}$$

Controlled Emissions:

control technique - watering
percent control - 50% (EPA Region VIII 1979)

(8.32 ton/4 mos) (0.5) = 4.16 ton/4 mos

(2.01 g/sec) (0.5) = 1.01 g/sec

(Not a PSD Source)

6. ACCESS ROAD TRAFFIC

EF = (0.6) (0.81s) $(S/30)^2$ [(365-W)/365] lb/VMT (EPA 1975)

s = 12%
S = 25 mph
W = 90 wet days

EF = (0.6) (0.81) (12) $(25/30)^2$ [(365-90)/365] lb/VMT = 3.05 lb/VMT

Operational Parameters:

(86 vehicles/day) (3.62 mi) = 311 VMT/day

Uncontrolled Emissions:

E = (3.05 lb/VMT) (311 VMT/day) = 948.6 lb/day

4 month emission rate:

$$\frac{(948.6 \text{ lb/day})\ (87 \text{ days/4 mos})\ (2 \text{ mos traffic/4 mos})}{(2{,}000 \text{ lb/ton})} = 20.63 \text{ ton/4 mos}$$

Short term emission rate:

$$\frac{(948.6 \text{ lb/day})\ (454 \text{ g/lb})}{(24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 4.98 \text{ g/sec}$$

Controlled Emissions:

control technique - 90% compaction
percent control - 80% (CDH 1980)
(20.63 ton/4 mos) (0.2) = 4.13 ton/4 mos
(4.98 g/sec) (0.2) = 1.00 g/sec

Assume that half of this emission rate is due to traffic associated with construction related activities (not a PSD source) and half is associated with mining operations (PSD source).

PSD emissions:	2.07 ton/4 mos	0.50 g/sec
NAAQS emissions:	4.13 ton/4 mos	1.00 g/sec

7. CONCRETE BATCH PLANT

a. transfer of sand and aggregate to elevated bins
EF = 0.04 lb/ton (EPA 1975)

b. cement unloading to elevated storage silos
EF = 0.23 lb/ton (EPA 1975)

c. Weight hopper loading of cement, sand, and aggregate
EF = 0.23 lb/ton (EPA 1975)

d. mixer loading of cement, sand, and aggregate for central mix plant
EF = 0.02 lb/ton (EPA 1975)

e. loading of transit mix truck
EF = 0.02 lb/ton (EPA 1975)

Operational Parameters:

83,000 lb/day cement
185,000 lb/day sand
352,000 lb/day aggregate
160 yd^3/day concrete

Uncontrolled Emissions:

process a. $E = \frac{(0.04 \text{ lb/ton})\ (435{,}000 \text{ lb/day})}{(2{,}000 \text{ lb/ton})} = 8.7 \text{ lb/day}$

process b. $E = \frac{(0.23 \text{ lb/ton})\ (83{,}000 \text{ lb/day})}{(2{,}000 \text{ lb/ton})} = 9.5 \text{ lb/day}$

process c & d. $E = \frac{(0.25 \text{ lb/ton})\ (620{,}000 \text{ lb/day})}{(2{,}000 \text{ lb/ton})} = 77.5 \frac{\text{lb}}{\text{day}}$

process e. $E = (0.02\ lb/ton)\ (2.025\ ton/yd^3)\ (160\ yd^3/day) = 6.5\ \frac{lb}{day}$

4 month emission rates:

a. $\frac{(8.7\ lb/day)\ (87\ day/4\ mos)}{2{,}000\ lb/ton} = 0.38\ ton/4\ mos$

b. 9.5 lb/day = 0.42 ton/4 mos

c & d. 77.5 lb/day = 3.37 ton/4 mos

e. 6.5 lb/day = 0.28 ton/4 mos

Short term emission rates:

a. $\frac{(8.7\ lb/day)\ (454\ g/lb)}{(24\ hrs/day)\ (3{,}600\ sec/hr)} = 0.05\ g/sec$

b. 9.5 lb/day = 0.05 g/sec

c & d. 77.5 lb/day = 0.41 g/sec
e. 6.5 lb/day = 0.04 g/sec

Controlled Emissions:

Control technique - baghouses on processes a., b., c., and d.
Percent control - 99% (EPA Region VIII 1979)

4 month emission rates:

a. (0.38 ton/4 mos) (0.01) = 0.00 ton/4 mos
b. (0.42 ton/4 mos) (0.01) = 0.00 ton/4 mos
c & d. (3.37 ton/4 mos) (0.01) = 0.03 ton/4 mos
e. 0.28 ton/4 mos

short term emission rates:

a. (0.05 g/sec) (0.01) = 0.00 g/sec
b. (0.05 g/sec) (0.01) = 0.00 g/sec
c & d. (0.41 g/sec) (0.01) = 0.00 g/sec
e. 0.04 g/sec

(Not a PSD Source)

8. TOPSOIL WIND EROSION

EF = 0.025 IKCLV tons/acre-yr (Woodruff and Siddoway 1976)

I = soil erodibility = 47 for clay loam (PEDCo 1974)

K = surface roughness factor = 1 (assumed worst case)

C = climatic factor = $\frac{0.345\ u^3}{(PE)^2} = \frac{(0.345)\ (7.7\ mph)^3}{(51)^2} = 0.0606$

U = 7.7 mph (RBOSC 1980)

PE = 51 (PEDCo 1974)

L = unsheltered field width factor = 1 (assumed worst case)

V = vegetative cover factor = 1 (assumed worst case)

EF = (0.025) (47) (1) (0.0606) (1) (1) = 0.0712 tons/acre - year

Erosion Parameters :

Surface area estimated from plenimeter and assuming all slopes are 3:1.

Topsoil Pile	Surface Area, Acres
1	9.3
2	3.2
3	4.6
4	5.3
5	6.5
6	2.3
7	2.5
8	1.5
9	3.0
10	2.2
TOTAL	40 Acres

Uncontrolled Emissions:

E = (0.0712 tons/acre-yr) (40 acres) = 2.85 tons/yr

4 month emission rate:

(2.85 ton/yr) (0.333) = 0.95 tons/4 mos

Short term emission rate:

$$\frac{(2.85 \text{ ton/yr})\ (2{,}000 \text{ lb/ton})\ (454 \text{ g/lb})}{(365 \text{ day/yr})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 0.08 \text{ g/sec}$$

Controlled Emissions:

control technique - rapid revegetation
percent control - 75% (EPA Region VIII 1979)

(0.95 ton/4 mos) (0.25) = 0.24 ton/4 mos

Short term emission rate remains the same because of the time required to revegetate.

(PSD and NAAQS Source)

1981 OPERATIONS

OVERBURDEN STRIPPING PHASE SEPTEMBER 1981 THROUGH DECEMBER 1981

1. OVERBURDEN REMOVAL

$$EF = \frac{(0.0018\ (s/5)\ (u/5)}{(M/2)^2\ (Y/6)}\ \text{lb/ton (CDH 1979)}$$

s = silt content = 25% (assumed)
U = average wind speed = 7.7 mph (average at C-a)
M = overburden moisture content = 2% (assumed)
Y = loader capacity = 12 yd^3

$$EF = \frac{(0.0018)\ (25/5)\ (7.7/5)}{(2/2)^2\ \ (12/6)} = 0.0069\ \text{lb/ton}$$

Operational Parameter:

738,296 yd^3 removed from areas of construction (Not a PSD Source)
1,758,904 yd^3 removed from the pit (PSD Source)

Uncontrolled Emissions:

E = (0.0069 lb/ton) (2,497,200 yd^3/4 mos) x
(1.825 ton/yd^3) = 31,446 lb/4 mos

= 15.72 ton/4 mos (NAAQS Source)
11.07 ton/4 mos (PSD Source)

Short term emission rate:

$$\frac{(31{,}446\ \text{lb/4 mos})\ (454\ \text{g/lb})}{(87\ \text{op days/4 mos})\ (24\ \text{hrs/day})\ (3{,}600\ \text{sec/hr})} = \begin{array}{l} 1.90\ \text{g/sec (NAAQS Source)} \\ 1.34\ \text{g/sec (PSD Source)} \end{array}$$

2. OVERBURDEN HAUL

$$EF = (0.6)(0.81s)(S/30)^2\ [(365-W)/365]\ (N/4)\ \text{lb/VMT (EPA 1975)}$$

$$EF = (0.6)(0.81)(12)(15/30)^2\ [(365-90)/365]\ (6/4)\ \text{lb/VMT} = 1.65\ \text{lb/VMT}$$

85 ton truck carries 47 yd^3 of overburden

Operational Parameters:

Overburden Source	Material Hauled, yd^3	One Way Dist, ft	VMT*
Over. to adj. haul	685,800	3,200	17,686
Over. to haul rd	637,000	3,600	18,482
Over. to off tract	64,400	9,300	4,827
Over. to shop ofc.	222,200	1,900	3,402
Over. to access	149,300	6,300	7,580
Haul rd. cut	500,000	3,700	14,910
Settling pond	100,000	200	161
Shale stock cut	138,500	2,300	2,567
TOTAL	2,497,200		69,615

$$* \text{ VMT} = \frac{(\text{total volume hauled, yd}^3)(2\text{x average distance, ft})}{(47 \text{ yd}^3/\text{trip})(5{,}280 \text{ ft/mi})}$$

Uncontrolled Emissions:

E = (1.65 lb/VMT) (69,615 VMT/4 mos) = 114,865 lb/4 mos

= 57.43 ton/4 mos

Short term emission rate:

$$\frac{(114{,}865 \text{ lb/4 mos})\ (454 \text{ g/lb})}{(87 \text{ op days/4 mos})(24 \text{ hrs/day})(3{,}600 \text{ sec/hr})} = 6.94 \text{ g/sec}$$

Controlled Emissions:

control technique - lignon sulfonate or equivalent palliative
percent control - 85

(57.43 ton/4 mos) (0.15) = 8.61 ton/4 mos

(6.94 g/sec) (0.15) = 1.04 g/sec

(Not a PSD Source)

3. OVERBURDEN DUMPING:

EF = 0.02 lb/ton (PEDCo 1977)

Operational Parameter:

2,497,200 yd^3 dumped in 4 mos

Uncontrolled Emissions:

$$E = (0.02 \text{ lb/ton})\ (2{,}497{,}200 \text{ yd}^3/4 \text{ mos})\ (1.825 \text{ ton/yd}^3) = 91{,}148 \frac{\text{lb}}{4 \text{ mos}}$$

= 45.57 ton/4 mos

Short term emission rate:

$$\frac{(91{,}148 \text{ lb}/4 \text{ mos})\ (454 \text{ g/lb})}{(87 \text{ op days}/4 \text{ mos})(24 \text{ hrs/day})(3{,}600 \text{ sec/hr})} = 5.51 \text{ g/sec}$$

(Not a PSD Source)

4. OVERBURDEN DRILLING

EF = 1.5 lb/hole (PEDCo 1978)

Operational Parameter:

675 holes/mo

Uncontrolled Emissions:

E = (1.5 lb/hole) (675 holes/mo) (4 mos) = 4,050 lb/4 mos

= 2.03 ton/4 mos

Short term emission rate:

$$\frac{(4{,}050 \text{ lb}/4 \text{ mos})\ (454 \text{ g/lb})}{(87 \text{ op days}/4 \text{ mos})\ (24 \text{ hrs/day})\ (3{,}600 \text{ sec/hr})} = 0.24 \text{ g/sec}$$

Controlled Emissions:

control technique - water injection
percent control - 90 (EPA Region VIII 1979)

(2.03 ton/4 mos) (0.1) = 0.2 ton/4 mos

(0.24 g/sec) (0.1) = 0.02 g/sec

(PSD and NAAQS Source)

5. OVERBURDEN BLASTING

EF = 49.8 lb/blast (PEDCo 1978)

Operational Parameter:

17 blasts/mo

Uncontrolled Emissions:

E = (49.8 lb/blast) (17 blasts/mos) (4 mo) = 3,386 lb/4 mos

= 1.69 ton/4 mos

Short term emission rate:

$$\frac{(3{,}386 \text{ lb}/4 \text{ mos})\ (454 \text{ g/lb})}{(87 \text{ op days}/4 \text{ mos})\ (24 \text{ hrs/day})\ (3{,}600 \text{ sec/hr})} = 0.20 \text{ g/sec}$$

(PSD and NAAQS Source)

6. HAUL ROAD CONSTRUCTION

EF = 32 lb/roadgrader - hr (PEDCo 1978)

Operational Parameter:

1,577 roadgrader - hrs/4 mos

need 3.5 months to actually construct haul road

Uncontrolled Emissions:

E = (32 lb/roadgrader-hr) x
(1,577 roadgrader hrs/4 mos) = 50,464 lb/4 mos

= 25.23 ton/4 mos

Short term emission rate:

$$\frac{(50{,}464 \text{ lb}/3.5 \text{ mos})\ (454 \text{ g/lb})}{(76 \text{ op days}/3.5 \text{ mos})\ (24 \text{ hrs/day})\ (3{,}600 \text{ sec/hr})} = 3.49 \text{ g/sec}$$

Controlled Emissions:

control technique - watering
percent control - 50 (PEDCo 1978)

(25.23 ton/4 mos) (0.5) = 12.62 ton/4 mos

(3.49 g/sec) (0.5) = 1.75 g/sec

(Not a PSD Source)

7. WATER TRUCK TRAFFIC

$EF = (0.6)\ (0.81s)\ (s/30)^2\ [(365-W)/365]\ (N/4)$ lb/VMT (EPA 1975)

EF (for 3,300 gal truck) = $(0.6)\ (0.81)\ (12)\ (10/30)^2$ x

[(365-90)/365] (10/4) lb/VMT

= 1.22 lb/VMT

EF (for 10,000 gal truck) = $(0.6)\ (0.81)\ (12)\ (10/30)^2$ x

[(365-90)/365] lb/VMT

= 0.49 lb/VMT

Operational Parameters

one 3,300 gal truck
two 10,000 gal truck
all three operating 2 hrs/day

(10 mph/truck) (2 hrs/day) (87 day/4 mos) = 1,740 VMT/truck-4 mos

Uncontrolled Emissions:

E (3,300 gal truck) = (1.22 lb/VMT) (1,740 VMT/4 mos) = 2,123 lb/4 mos

= 1.06 ton/4 mos

E (10,000 gal truck) = (2 trucks) (0.49 lb/VMT) x (1,740 VMT/truck - 4 mos) = 1,705 lb/4 mos

= 0.85 ton/4 mos

Short term emission rate:

$$\frac{(3{,}828 \text{ lb/4 mos})\ (454 \text{ g/lb})}{(87 \text{ op days/4 mos})\ (24 \text{ hrs/day})\ (3{,}600 \text{ sec/hr})} = 0.23 \text{ g/sec}$$

Controlled Emissions:

control technique - lignon sulfonate or similar palliative
percent control - 85

(1.91 ton/4 mos) (0.15) = 0.29 ton/4 mos

(0.23 g/sec) (0.15) = 0.03 g/sec

(Not a PSD Source)

8. ACCESS ROAD TRAFFIC (See Construction Phase, Calculation 6)

EF = 3.05 lb/VMT

Operational Parameter

311 VMT/day

Uncontrolled Emissions:

948.6 lb/day

4 month emission rate:

41.26 ton/4 mos

Short term emission Rate:

4.98 g/sec

Controlled Emissions:

control technique - 90% compaction and the application of lignon sulfonate or other palliative

percent control - 90% from compaction (CDH 1980) and an additional 85% from the palliative (EPA Region VIII 1979)

(41.26 ton/4 mos) (0.20) (0.15) = 1.24 ton/4 mos

(4.98 g/sec) (0.20) (0.15) = 0.15 g/sec

Assume 50% is associated with PSD activities and 50% is associated with construction activities.

PSD emissions:	0.62 ton/4 mos	0.08 g/sec
NAAQS emissions:	1.24 ton/4 mos	0.15 g/sec

9. CONCRETE BATCH PLANT (See Construction Phase, Calculation 7)

process a.	EF = 0.04 lb/ton
process b.	EF = 0.23 lb/ton
process c.	EF = 0.23 lb/ton
process d.	EF = 0.02 lb/ton
process e.	EF = 0.02 lb/ton

Operational Parameters:

83,000	lb/day cement
185,000	lb/day sand
352,000	lb/day aggregate
160	yd^3/day concrete

Uncontrolled Emissions:

a.	8.7	lb/day
b.	9.5	lb/day
c. & d.	77.5	lb/day
e.	6.5	lb/day

4 month emission rates:

a.	0.38 ton/4 mos
b.	0.42 ton/4 mos
c. & d.	3.37 ton/4 mos
e.	0.28 ton/4 mos

Short term emission rates:

a.	0.05 g/sec
b.	0.05 g/sec
c. & d.	0.41 g/sec
e.	0.04 g/sec

Controlled Emissions:

a.	0.00 tons/4 mos	0.00 g/sec
b.	0.00 tons/4 mos	0.00 g/sec
c. & d.	0.03 tons/4 mos	0.00 g/sec
e.	0.28 tons/4 mos	0.04 g/sec

(Not a PSD Source)

10. TOPSOIL WIND EROSION (See Construction Phase, Calculation 8)

EF = 0.0712 tons/acre-yr

Erosion Parameter:

40 acres

Uncontrolled Emissions:

2.85 tons/yr

4 month emission rate:

0.95 tons/4 mos

Short term emission rate:

0.08 g/sec

Controlled Emissions:

0.24 ton/4 mos

0.08 g/sec

(PSD and NAAQS Source)

11. OVERBURDEN WIND EROSION

EF = 0.025 IKCLV tons/acre-yr (Woodruff and Siddoway 1976)
I = 38 for overburden (rocky gravelly material)
K = 1 (assumed worst case)
C = 0.0606 (See Construction Phase, Calculation 8)
L = 1 (assumed worst case)
V = 1 (assumed worst case)

EF = (0.025) (38) (1) (0.0606) (1) (1) = 0.0576 ton/acre yr

Erosion Parameters:

Assume the amount of overburden going to construct the haul road (637,000 yd^3 in 1981) is not a wind erosion source because haul road is immediately constructed and surface of haul road protects overburden material underneath of entraining into ambient air.

Overburden Material	Acreage*
to adjacent haul road	32.6
to offtract fill	1.4
to shop/office fill	12.2
haul road cut to offtract	11.1
settling pond	10.3
shale stockpile to offtract	3.1
TOTAL	70.7 acres

*by plenimeter

Uncontrolled Emissions:

E = (0.0576 ton/acre-yr) (71 acres) = 4.09 ton/yr

4 month emission rate:

(4.09 ton/yr) (0.333) = 1.36 ton/4 mos

Short term emission rate:

$$\frac{(1.36 \text{ ton/4 mos})\ (2{,}000 \text{ lb/ton})\ (454 \text{ g/lb})}{(122 \text{ days/4 mos})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 0.12 \text{ g/sec}$$

(PSD and NAAQS Source)

12. DISTURBED AREAS EROSION (See Calculation 11)

EF = 0.0576 ton/acre-yr

Erosion Parameters:

301 acres (by plenimeter)

Uncontrolled Emissions:

E = (0.0576 ton/acre-yr) (301 acres) = 17.34 ton/yr

4 month emission rate:

(17.34 ton/yr) (0.333) = 5.78 ton/4 mos

Short term emission rate:

$$\frac{(5.78 \text{ ton/4 mos})\ (2{,}000 \text{ lb/ton})\ (454 \text{ g/lb})}{(122 \text{ days/4 mos})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 0.50 \text{ g/sec}$$

(PSD and NAAQS Source)

APPENDIX B-3

1982 OPERATIONS

1982 OPERATIONS

1. OVERBURDEN REMOVAL

EF = 0.0069 lb/ton (See 1981 Overburden Stripping Phase Calculation 1)

Operational Parameter:

3,296,000 yd^3/yr

Uncontrolled Emissions

E = (0.0069 lb/ton)(3,296,000 yd^3/yr)(1.825 ton/yd^3) = 41,505 lb/yr

= 20.75 ton/yr

Short term emission rate:

$$\frac{(41{,}505 \text{ lb/yr})\ (454 \text{ g/lb})}{(261 \text{ op days/yr})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 0.84 \text{ g/sec}$$

(PSD and NAAQS Source)

2. OVERBURDEN HAULING

EF = 1.65 lb/VMT (See 1981 Overburden Stripping Phase, Calculation 2)

Operational Parameter:

VMT = (total volume hauled)(distance/trip)/(volume hauled/trip)
= 247,038 VMT/yr

Uncontrolled Emissions:

E = (1.65 lb/VMT) (247,038 VMT/yr) = 407,613 lb/yr

= 203.81 ton/yr

Controlled Emissions:

Control factor = 0.15 (85% control) (Lignon sulfonate or equivalent)

E = (203.81 ton/yr) (0.15) = 30.57 lb/yr

Short term emission rate:

$$\frac{(30.57 \text{ ton/yr})\ (2{,}000 \text{ lb/ton})\ (454 \text{ g/lb})}{(261 \text{ day/yr})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 1.23 \text{ g/sec}$$

(Not a PSD Source)

3. OVERBURDEN DUMPING

EF = 0.02 lb/ton (PEDCo 1978)

Operational Parameter:

3,296,000 yd^3/yr

Uncontrolled Emissions:

E = (0.02 lb/ton) (3,296,000 yd^3) (1.825 ton/yd^3) = 120,304 lb/yr
= 60.15 ton/yr

Short term emission rate:

$$\frac{(120{,}304 \text{ lb/yr})\ (454 \text{ g/lb})}{(261 \text{ day/yr})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 2.42 \text{ g/sec}$$

(Not a PSD Source)

4. TOPSOIL REMOVAL

EF = 0.38 lb/yd^3

Operational Parameter:

252,500 yd^3/yr

Uncontrolled Emissions:

E = (0.38 lb/yd^3) (252,500 yd^3/yr) = 95,950 lb/yr
= 47.98 ton/yr

Controlled Emissions:

Control factor = 0.50 (50% control for watering)

E = (47.98 ton/yr) (0.5) = 23.99 ton/yr

Short term emissions:

$$\frac{(23.99 \text{ ton/yr})\ (2{,}000 \text{ lb/ton})\ (454 \text{ g/lb})}{(261 \text{ day/yr})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 0.97 \text{ g/sec}$$

(Not a PSD Source)

5. TOPSOIL HAULING

EF = 0.703 lb/VMT (See 1981 Construction Phase, Calculation 2)

Operational Parameter:

VMT = (total volume hauled) (distance/trip) (volume hauled/trip)
= 6,391 VMT/yr

Uncontrolled Emissions:

E = (0.703 lb/VMT) (6,391 VMT/yr) = 4,493 lb/yr
= 2.25 ton/yr

Controlled Emissions:

Control factor = 0.15 (85% control for lignon sulforate or equivalent)

E = (2.25 ton/yr) (0.15) = 0.34 ton/yr

Short term emissions:

$$\frac{(0.34 \text{ ton/yr})\ (2{,}000 \text{ lb/ton})\ (454 \text{ g/lb})}{(261 \text{ day/yr})\ (24 \text{ hrs/day})\ (3{,}600 \text{ sec/hr})} = 0.01 \text{ g/sec}$$

(Not a PSD Source)

6. TOPSOIL DUMPING

EF = 0.03 lb/yd^3

Operational Parameter:

252,500 yd^3/yr

Uncontrolled Emissions:

E = (0.03 lb/yd^3) (252,500 yd^3/yr) = 7,575 lb/yr
= 3.79 ton/yr

Controlled Emissions:

Control factor = 0.5 (50% control for watering)

E = (3.79 ton/yr) (0.5) = 1.90 ton/yr

Short term emissions:

$$\frac{(1.90 \text{ ton/yr})\ (2{,}000 \text{ lb/ton})\ (454 \text{ g/lb})}{(261 \text{ day/yr})\ (24 \text{ hrs/day})\ (3{,}600 \text{ sec/hr})} = 0.08 \text{ g/sec}$$

(Not a PSD Source)

7. ACCESS ROAD TRAFFIC

EF = 3.05 lb/VMT (See 1981 Construction Phase, Calculation 6)

Operational Parameter:

311 VMT/day

Uncontrolled Emissions:

E = (3.05 lb/VMT) (311 VMT/day) (261 day/yr) = 247,572 lb/yr
= 123.79 ton/yr

Controlled Emissions:

Control factor = 0.03 (80% control for compaction, 85% for lignon sulfonate or equivalent)

E = (247,572 lb/yr) (0.03) = 7,427 lb/yr
= 3.71 ton/yr

Short term emissions:

$$\frac{(7{,}427 \text{ lb/yr})\ (454 \text{ g/lb})}{(261 \text{ day/yr})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 0.15 \text{ g/sec}$$

Assume 80% is associated with PSD activities and 20% is associated with construction activities.

PSD emissions: 2.97 ton/yr 0.12 g/sec
NAAQS emissions: 3.71 ton/yr 0.15 g/sec

8. TOPSOIL EROSION

EF = 0.0712 ton/acre-yr (See 1981 Construction Phase, Calculation 8)

Operational Parameter:

60 acres

Uncontrolled Emissions:

E = (0.0712 ton/acre-yr) (60 acres)
= 4.27 ton/yr

Controlled Emissions:

control technique - rapid revegetation
control factor = 0.25 (75%, EPA, Region VIII)

E = (4.27 ton/yr) (0.25)
= 1.07 ton/yr

Short term emissions:

$$\frac{(1.07 \text{ ton/yr})\ (2{,}000 \text{ lb/ton})\ (454 \text{ g/lb})}{(365 \text{ day/yr})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 0.03 \text{ g/sec}$$

(PSD and NAAQS Source)

9. OVERBURDEN EROSION

EF = 0.0576 ton/acre-yr (See 1981 Overburden Stripping Phase, Calculation 8)

Operational Parameter

In 1982 there will be no spent shale deposited inside the berms, thus the overburden wind erosion is based on the surface area of the entire berm, both inside, top and outside. The inside is assumed to have the same surface area as the outside. Since both the inside and outside surfaces are sloped, their surface area must be estimated with both the plenimeter measurement of the base acreage and the slope of the berm surface which is equal to 1/3. The acreage of the flat area of the berm can be directly estimated from the plenimeter measurement.

total acreage = 166 acres

Uncontrolled Emissions:

E = (0.0576 ton/acre-yr) (166 acres)
= 9.56 ton/yr

Short term emissions:

$$\frac{(9.56 \text{ ton/yr})\ (2{,}000 \text{ lb/ton})\ 454 \text{ g/lb})}{(365 \text{ day/yr})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 0.28 \text{ g/sec}$$

(PSD and NAAQS Source)

10. CONCRETE BATCH PLANT (See 1981 Construction Phase, Calculation 7)

Uncontrolled Emissions:

a - d. = 95.7 lb/day
e. = 6.5 lb/day

Controlled Emissions:

99% control for baghouse on processes a-d

E = [(95.7 lb/day) (0.01) + 6.5 lb/day] (261 day/yr) = 1,946 lb/yr
= 0.97 ton/yr

Short term emissions:

$$\frac{(1{,}946 \text{ lb/yr})\ (454 \text{ g/lb})}{(261 \text{ day/yr})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 0.04 \text{ g/sec}$$

(Not a PSD Source)

11. OVERBURDEN DRILLING

EF = 1.5 lb/hole (PEDCo, 1978)

Operational Parameter:

675 holes/month

Uncontrolled Emissions:

E = (1.5 lb/hole)(675 holes/mo)(12 mos/yr) = 12,150 lb/yr
= 6.08 ton/yr

Controlled Emissions:

Control factor = 0.1 (90% control for water injection)

E = (6.08 ton/yr) (0.1) = 0.61 ton/yr

Short term emissions:

$$\frac{(0.61 \text{ ton/yr})\ (2{,}000 \text{ lb/ton})\ (454 \text{ g/lb})}{(261 \text{ days/yr})(24 \text{ hrs/day})(3{,}600 \text{ sec/hr})} = 0.02 \text{ g/sec}$$

(PSD and NAAQS Source)

12. OVERBURDEN BLASTING

EF = 49.8 lb/blast

Operational Parameter:

17 blasts/month

Uncontrolled Emissions:

E = (49.8 lb/blast) (17 blast/month) (12 month/yr) = 10,159 lb/yr
= 5.07 ton/yr

Short term emissions:

$$\frac{(10{,}159 \text{ lb/yr})\ (454 \text{ g/lb})}{(261 \text{ day/yr})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 0.20 \text{ g/sec}$$

(PSD and NAAQS Source)

13. DISTURBED AREAS EROSION

EF = 0.0576 ton/acre-yr (See 1981 Overburden Stripping Phase, Calculation 10)

Operational Parameter:

301 acres

Uncontrolled Emissions:

E = (0.0576 ton/acre-yr) (301 acres)
= 17.34 ton/yr

Short term emissions:

$$\frac{(17.34\ \text{ton/yr})\ (2{,}000\ \text{lb/ton})\ (454\ \text{g/lb})}{(365\ \text{day/yr})\ (24\ \text{hr/day})\ (3{,}600\ \text{sec/hr})} = 0.50\ \text{g/sec}$$

(PSD and NAAQS Source)

14. WATER TRUCK TRAFFIC (See 1981 Overburden Stripping Phase, Calculation 7)

Uncontrolled Emissions:

E = 11,484 lb/yr
= 5.74 ton/yr

Controlled Emissions:

Control factor = 0.15 (85% control for lignon sulfonate or equivalent)

E = (5.74 ton/yr) (0.15)
= 0.86 ton/yr

Short term emissions:

$$\frac{(0.86\ \text{ton/yr})\ (2{,}000\ \text{lb/ton})\ (454\ \text{g/lb})}{(261\ \text{day/yr})\ (24\ \text{hr/day})\ (3{,}600\ \text{sec/hr})} = 0.03\ \text{g/sec}$$

(Not a PSD Source)

1983 OPERATIONS

1. OVERBURDEN REMOVAL

EF = 0.0069 lb/ton (See 1981 Overburden Stripping Phase, Calculation 1)

Operational Parameter:

2,483,600 yd^3/yr

Uncontrolled Emissions:

E = (0.0069 lb/ton) (2,483,600 yd^3/yr) (1.825 ton/yd^3) = 31,275 lb/yr
= 15.64 ton/yr

Short term emissions:

$$\frac{(31{,}275 \text{ lb/yr})\ (454 \text{ g/lb})}{(261 \text{ day/yr})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 0.63 \text{ g/sec}$$

(PSD and NAAQS Source)

2. OVERBURDEN HAULING

EF = 1.65 lb/VMT (See 1981 Overburden Stripping Phase, Calculation 2)

Operational Parameters:

293 yd^3 overburden to containment dike (7,800 ft)
2,190,600 yd^3 overburden to East Gulch fill (400 ft)

$$\text{VMT} = \frac{(2{,}190{,}600 \text{ yd}^3)(2 \times 40 \text{ ft})}{(47 \text{ yd}^3/\text{trip})(5{,}280 \text{ ft/mi})} + \frac{(293{,}000 \text{ yd}^3)(2 \times 7{,}800 \text{ ft})}{(47 \text{ yd}^3/\text{trip})(5{,}280 \text{ ft/mi})}$$

= 7,062 + 18,419
= 25,481 (NAAQS Source)
7,062 (PSD Source)

Uncontrolled Emissions:

E = (1.65 lb/VMT) (25,481 VMT/yr) = 42,044 lb/yr
= 21.02 ton/yr

Controlled Emissions:

Control factor = 0.15 (85% control for lignon sulfonate or equivalent)

E = (21.02 ton/yr) (0.15) = 3.15 ton/yr (NAAQS Source)
0.87 ton/yr (PSD Source)

Short term emissions:

$$\frac{(3.15\ \text{ton/yr})\ (2{,}000\ \text{lb/ton})\ (454\ \text{g/lb})}{(261\ \text{day/yr})\ (24\ \text{hr/day})\ (3{,}600\ \text{sec/hr})}$$

$\approx$ 0.13 g/sec (NAAQS Source)
= 0.04 g/sec (PSD Source)

3. OVERBURDEN DUMPING

EF = 0.02 lb/ton (See 1981 Overburden Stripping Phase, Calculation 3)

Operational Parameter

293,000 yd^3 to containment dike
2,190,600 yd^3 to East Gulch fill

Uncontrolled Emissions:

E = (0.02) (2,483,600 yd^3/yr) (1.825 ton/yd^3) = 90,651 lb/yr
= 45.33 ton/yr (NAAQS Source)
39.98 ton/yr (PSD Source)

Short term emissions:

$$\frac{(90{,}651\ \text{lb/yr})\ (454\ \text{g/lb})}{(261\ \text{day/yr})\ (24\ \text{hr/day})\ (3{,}600\ \text{sec/hr})}$$

= 1.83 g/sec (NAAQS Source)
= 1.61 g/sec (PSD Source)

4. TOPSOIL REMOVAL

EF = 0.38 lb/yd^3

Operational Parameter:

16,900 yd^3/yr

Uncontrolled Emissions:

E = (0.38 lb/yd^3) (16,900 yd^3/yr) = 6,422 lb/yr
= 3.21 ton/yr

Controlled Emissions:

Control Factor = 0.5 (50% control for watering)
E = (3.21 ton/yr) (0.5) = 1.61 ton/yr

Short term emissions:

$$\frac{(1.61\ \text{ton/yr})\ (2{,}000\ \text{lb/ton})\ (454\ \text{g/lb})}{(261\ \text{day/yr})\ (24\ \text{hr/day})\ (3{,}600\ \text{sec/hr})} = 0.06\ \text{g/sec}$$

(PSD and NAAQS Source)

5. TOPSOIL HAULING

EF = 0.703 lb/VMT (See 1981 Construction Phase, Calculation 2)

Operational Parameter:

VMT = (total volume hauled) (distance/trip)/(volume hauled/trip)
= 414 VMT/yr

Uncontrolled Emissions:

E = (0.703 lb/VMT) (414 VMT/yr) = 291 lb/yr
= 0.15 ton/yr

Controlled Emissions:

Control factor = 0.15 (85% control for lignon sulfonate or equivalent)

E = (0.15 ton/yr) (0.15) = 0.02 ton/yr

Short term emissions:

$$\frac{(0.02\ \text{ton/yr})\ (2{,}000\ \text{lb/ton})\ (454\ \text{g/lb})}{(261\ \text{day/yr})\ (24\ \text{hr/day})\ (3{,}600\ \text{sec/hr})} = 0.00\ \text{g/sec}$$

(PSD and NAAQS Source)

6. TOPSOIL DUMPING

EF = 0.03 lb/yd^3

Operational Parameter:

16,900 yd^3/yr

Uncontrolled Emissions:

E = (0.03 lb/yd^3) (16,900 yd^3/yr) = 507 lb/yr
= 0.25 ton/yr

Controlled Emissions:

Control factor = 0.5 (50% control for watering)

E = (0.25 ton/yr) (0.5)
= 0.13 ton/yr

Short term emissions:

$$\frac{(0.13\ \text{ton/yr})\ (2{,}000\ \text{lb/ton})\ (454\ \text{g/lb})}{(261\ \text{day/yr})\ (24\ \text{hr/day})\ (3{,}600\ \text{sec/hr})} = 0.01\ \text{g/sec}$$

(PSD and NAAQS Source)

7. ORE REMOVAL

$$EF = \frac{(0.0018)\ (s/5)\ (u/5)}{(M/2)^2\ (Y/6)} \text{ lb/ton (CDH 1979)}$$

Where: s = percent silt content = 25%
u = wind speed in mph = 7.7 mph
M = moisture content = 20%
Y = bucket size = 12 yd^3

$$EF = \frac{(0.0018)\ (25/5)\ (7.7/5)}{(20/2)^2\ (12/6)} = 0.000069 \text{ lb/ton}$$

Operational Parameter:

1,200,000 ton/yr

Uncontrolled Emissions:

E = (0.000069 lb/ton) (1,200,000 ton/yr) = 83 lb/yr
= 0.04 ton/yr

Short term emissions:

$$\frac{(83 \text{ lb/yr})\ (454 \text{ g/lb})}{(261 \text{ day/yr})\ (24 \text{ hr/day}\ (3{,}600 \text{ sec/hr})} = 0.00 \text{ g/sec}$$

(PSD and NAAQS Source)

8. ORE HAULING

EF = 1.65 lb/VMT (See 1981 Overburden Stripping Phase, Calculation 2)

Operational Parameter:

VMT = (total volume hauled)(distance/trip)/(volume hauled/trip)
= 41,332 VMT/yr

Uncontrolled Emissions:

E = (1.65 lb/VMT) (41,332 VMT/yr) = 68,198 lb/yr
= 34.19 ton/yr

Controlled Emissions:

Control Factor = 0.15 (85% Control for lignon sulfonate, or equivalent)

E = (34.10) (0.15)
= 5.12 ton/yr

Short term emissions:

$$\frac{(5.12\ \text{ton/yr})\ (2{,}000\ \text{lb/ton})\ (454\ \text{g/lb})}{(261\ \text{day/yr})\ (24\ \text{hr/day})\ (3{,}600\ \text{sec/hr})} = 0.21\ \text{g/sec}$$

(PSD and NAAQS Source)

9. ORE DUMPING

EF = 0.000069 lb/ton (based on Calculation 7 and the fact that the ore is still very wet)

Operational Parameter:

1,200,000 ton/yr

Uncontrolled Emissions:

E = (0.000069 lb/ton) (1,200,000 ton/yr) = 83 lb/yr
= 0.04 ton/yr

Short term emissions:

$$\frac{(83\ \text{lb/yr})\ (454\ \text{g/lb})}{(261\ \text{day/yr})\ (24\ \text{hr/day})\ (3{,}600\ \text{sec/hr})} = 0.00\ \text{g/sec}$$

(PSD and NAAQS Source)

10. WATER TRUCK TRAFFIC

EF = 1.22 lb/VMT (3,300 galtruck)
EF = 0.49 lb/VMT (10,000 gal truck)
(See 1981 Overburden Stripping Phase, Calculation 7)

Operational Parameters:

5,220 VMT/yr (3,300 gal trucks)
10,440 VMT/yr (10,000 gal trucks)

Uncontrolled Emissions:

E = (1.22 lb/VMT) (5,220 VMT/yr) + (0.49 lb/VMT) (10,440 VMT/yr)
= 11,484 lb/yr
= 5.74 ton/yr

Controlled Emissions:

Control factor = 0.15 (85% control for lignon sulfonate or equivalent)

E = (5.74 ton/yr) (0.15)
= 0.86 ton/yr

Short term emissions:

$$\frac{(0.86\ \text{ton/yr})\ (2{,}000\ \text{lb/ton})\ (454\ \text{g/lb})}{(261\ \text{day/yr})\ (24\ \text{hr/day})\ (3{,}600\ \text{sec/hr})} = 0.03\ \text{g/sec}$$

(PSD and NAAQS Source)

11. ACCESS ROAD TRAFFIC

See 1982, Calculation 7

Controlled Emissions:

E = 3.71 ton/yr

Short term emissions:

0.15 g/sec

(PSD and NAAQS Source)

12. TOPSOIL EROSION

See 1982, Calculation 8

Controlled Emissions:

E = 1.07 ton/yr

Short term emissions:

0.03 g/sec

(PSD and NAAQS Source)

13. OVERBURDEN EROSION

See 1982, Calculation 9

Uncontrolled Emissions:

E = 9.56 ton/yr

Controlled Emissions:

Control factor = 0.25 (75% Control for rapid revegetation)

E = (9.56 ton/yr) (0.25) = 2.39 ton/yr

Short term emissions:

$$\frac{(2.39\ \text{ton/yr})\ (2{,}000\ \text{lb/ton})\ (454\ \text{g/lb})}{(365\ \text{day/yr})\ (24\ \text{hr/day})\ (3{,}600\ \text{sec/hr})} = 0.07\ \text{g/sec}$$

(PSD and NAAQS Source)

14. ORE STOCKPILE WIND EROSION

EF = 0.025 IKCLV
See 1981 Construction Phase, Calculation 8. Except here use I = 5. The actual value of I is probably close to zero due to the very small faction of fines in the oil shale.

EF = (0.025) (5) (0.0606) (1.0) (1.0)
= 0.00758 ton/acre-yr

Operational Parameter:

The area of the sloped surface of the stockpiles is calculated from the base area of the piles and an assumed slope of ½.

Total area

Stockpile 1	16.8 acres
Stockpile 2	12.1 acres

Uncontrolled Emissions:

E = (0.00758 ton/acre-yr) (16.8 + 12.1 acres)
= 0.22 ton/yr

Short term emissions:

$$\frac{(0.22 \text{ ton/yr})\ (2{,}000 \text{ lb/ton})\ (454 \text{ g/sec})}{(365 \text{ day/yr})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 0.01 \text{ g/sec}$$

(PSD and NAAQS Source)

15. ORE AND OVERBURDEN DRILLING

See 1982, Calculation 11

Controlled Emissions:

E = 0.61 ton/yr

Short term emissions:

0.02 g/sec

(PSD and NAAQS Source)

16. BLASTING

See 1982, Calculation 12

Uncontrolled Emissions:

E = 5.07 ton/yr

Controlled Emissions:

Control factor = 0.5 (50% control assumed because blasts are in aquifer)

E = (5.07 ton/yr) (0.5) = 2.54 ton/yr

Short term emissions:

$$\frac{(2.54 \text{ ton/yr})\ (2{,}000 \text{ lb/ton})\ (454 \text{ g/lb})}{(261 \text{ day/yr})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 0.10 \text{ g/sec}$$

(PSD and NAAQS Source)

17. DISTURBED AREAS EROSION

See 1982, Calculation 13

Controlled Emissions:

E = 17.34 ton/yr

Short term emissions:

0.50 g/sec

(PSD and NAAQS Source)

18. RUN OF MINE ORE LOAD OUT FROM ORE STOCKPILE

$$EF = \frac{0.0018\ (\bar{s}/5)^{s}(\bar{u}/5)^{u}}{(M/2)^2\ \ (Y/6)} \text{ lb/ton (CDH 1979)}$$

$$EF = \frac{(0.0018)(25/5)(7.7/5)}{(5/2)^2\ (12/6)} = 0.0011 \text{ lb/ton}$$

Operational Parameters:

4,400 ton/day
50% annual online rate

Uncontrolled Emissions:

E = (0.0011 lb/ton) (4,400 ton/day) (365 day/yr) (0.5) = 883 lb/yr
= 0.44 ton/yr

Short term emission rate:

$$\frac{(0.0011 \text{ lb/ton})\ (4{,}400 \text{ ton/day})\ (454 \text{ g/lb})}{(24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 0.03 \text{ g/sec}$$

(PSD and NAAQS Source)

19. RUN OF MINE LOAD IN TO PRIMARY CRUSHER HOPPER

$$EF = \frac{0.0018\ (s/5)(u/5)}{(M/2)^2}\ \text{lb/ton (CDH 1979)}$$

$$EF = \frac{(0.0018)(25/5)(7.7/5)}{(5/2)^2} = 0.0022\ \text{lb/ton}$$

Operational Parameters:

4,400 ton/day
50 % annual online rate

Uncontrolled Emissions:

E = (0.0022 lb/ton) (4,400 ton/day) (365 day/yr) x (0.5 cap. fac.) = 1,767 lb yr
= 0.88 ton/yr

Short term emission rate:

$$\frac{(0.0022\ \text{lb/ton})\ (4{,}400\ \text{ton/day})\ (454\ \text{g/lb})}{(24\ \text{hr/day})\ (3{,}600\ \text{sec/hr})} = 0.05\ \text{g/sec}$$

(PSD and NAAQS Source)

20. PRIMARY CRUSHING/SCREENING

EF = 0.02 lb/ton crushing (PEDCo 1978)
EF = 0.10 lb/ton screening (PEDCo 1978)
Total EF = 0.12 lb/ton

Uncontrolled Emissions:

E = (0.12 lb/ton) (803,000 ton/yr) = 96,360 lb/yr
= 48.18 ton/yr

Short term emission rate:

$$\frac{(0.12\ \text{lb/ton})\ (4{,}400\ \text{ton/day})\ (454\ \text{g/lb})}{(24\ \text{hrs/day})\ (3{,}600\ \text{sec/hr})} = 2.77\ \text{g/sec}$$

Controlled Emissions:

Control technique - baghouse
Percent Control - 99% (EPA Region VIII 1979)

(48.18 ton/yr) (0.01) = 0.48 ton/yr

(2.77 g/sec) (0.01) = 0.03 g/sec

(PSD and NAAQS Source)

21. SECONDARY CRUSHING/SCREENING

EF = 0.06 lb/ton crushing (PEDCo 1978)
EF = 0.10 lb/ton screening (PEDCo 1978)
Total EF = 0.16 lb/ton

Uncontrolled Emissions

E = (0.16 lb/ton) (803,000 ton/yr) = 128,480 lb/yr
= 64.24 ton/yr

Short term emission rate:

$$\frac{(0.16 \text{ lb/ton})\ (4{,}400 \text{ ton/day})\ (454 \text{ g/lb})}{(24 \text{ hrs/day})\ (3{,}600 \text{ sec/hr})} = 3.70 \text{ g/sec}$$

Controlled Emissions:

Control technique - baghouse
percent control - 99% (EPA Region VIII 1979)

(64.24 ton/yr) (0.01) = 0.64 ton/yr

(3.7 g/sec) (0.01) = 0.04 g/sec

(PSD and NAAQS Source)

22. CRUSHED ORE CONVEYING TO BUILDING CONTAINING CRUSHED ORE STOCKPILE

EF = 0.2 lb/ton (PEDCo 1978)

Uncontrolled Emissions:

E = (0.2 lb/ton) (803,000 ton/yr) = 160,600 lb/yr
= 80.3 ton/yr

Short term emission rate:

$$\frac{(0.2 \text{ lb/ton})\ (4{,}400 \text{ ton/day})\ (454 \text{ g/lb})}{(24 \text{ hrs/day})\ (3{,}600 \text{ sec/hr})} = 4.62 \text{ g/sec}$$

Controlled Emissions:

Control technique - baghouse
percent control - 99% (EPA Region VIII 1979)

(80.3 ton/yr) (0.01) = 0.8 ton/yr

(4.62 g/sec) (0.01) = 0.05 g/sec

(PSD and NAAQS Source)

23. CRUSHED ORE LOAD OUT FROM BUILDING CONTAINING CRUSHED ORE STOCKPILE

EF = 0.05 lb/ton (PEDCo 1978)

Operational Parameters:
4,400 ton/day
50% annual online rate

Uncontrolled Emissions:

E = (0.05 lb/ton)(4,400 ton/day)(365 day/yr)(0.5) = 40,150 lb/yr
= 20.08 ton/yr

Short term emission rate:

$$\frac{(0.05\ \text{lb/ton})(4{,}400\ \text{ton/day})(454\ \text{g/lb})}{(24\ \text{hr/day})(3{,}600\ \text{sec/hr})} \quad 1.16\ \text{g/sec}$$

Controlled Emissions:

Control Technique - baghouse
Percent control - 99% (EPA Region VIII 1979)

(20.08 ton/yr (0.01) = 0.20 ton/yr

(1.16 g/sec) (0.01) = 0.01 g/sec

(PSD and NAAQS Source)

24. CRUSHED ORE CONVEYING TO FEED HOPPER "UPSTREAM" OF BELTAVATOR

EF = 0.2 lb/ton (PEDCo 1978)

99% control with baghouse (EPA Region VIII 1979)

As per Calculation 22

0.80 ton/yr
0.05 g/sec
(PSD and NAAQS Source)

25. CRUSHED ORE TRANSFER TO LURGI FEED HOPPER VIA BELTAVATOR

EF = 0.2 lb/ton (PEDCo 1978)

99% control with baghouse (EPA Region VIII 1979)

As per Calculation 22

0.80 ton/yr
0.05 g/sec

(PSD and NAAQS Source)

26. PROCESSED SHALE TRANSFER VIA ROTARY FEEDER AND CONVEYER TO COLLECTING HOPPER

EF = 0.2 lb/ton (PEDCo 1978)

99% control with baghouse (EPA Region VIII 1979)

As per Calculation 22

0.80 ton/yr
0.05 g/sec

(PSD and NAAQS Source)

27. PROCESSED SHALE TRANSFER FROM THE COLLECTING HOPPER TO PROCESSED SHALE DISPOSAL AREA

EF = 0.2 lb/ton (PEDCo 1978)

99% control with baghouse (EPA Region VIII 1979)

As per Calculation 22
0.80 ton/yr
0.05 g/sec

(PSD and NAAQS Source)

28. PROCESSED SHALE DISPOSAL VIA STACKER IN PROCESSED SHALE DISPOSAL AREA

EF = 0.2 lb/ton (PEDCo 1978)

90% control assumed because processed shale is moisturized

As per Calculation 22 but with 90% control

8.03 ton/yr
0.46 g/sec

(PSD and NAAQS Source)

29. PROCESSED SHALE WIND EROSION

EF = 0.025 IKCLV (Woodruff and Siddoway 1976)

Although the processed shale is wet, it will dry within a few days (Golder 1980). Dry processed shale can have a large percentage of fine particulate and therefore a potentially large value for the soil erodibility parameter "I". However, RBOSC tests show that wet processed shale bonds to itself much like concrete with a very hard surface once it has set-up. Also, RBOSC wind tunnel tests (1980b) did not show any measurable erosion of processed shale piles (piles were compacted). However, the sensivity of the wind tunnel tests was not great enough to say, absolutely, there will be no erosion. In addition, it is possible that the actual processed shale piles will be uncompacted.

As a first approximation, assume the wind erosion of the processed shale piles to be equal (per unit area) to the overburden piles.

EF = 0.0576 tons/acre year

Erosion Parameter:

30 acres (by plenimeter)

Uncontrolled Emissions:

(0.0576 ton/acre-yr) (30 acres) = 1.73 ton/yr

Short term emission rate:

$$\frac{(1.73\ \text{ton/yr})\ (2{,}000\ \text{lb/ton})\ (454\ \text{g/lb})}{(365\ \text{days/yr})\ (24\ \text{hr/day})\ (3{,}600\ \text{sec/hr})} = 0.05\ \text{g/sec}$$

(PSD and NAAQS Source)

1984 OPERATIONS

1. OVERBURDEN REMOVAL

EF = 0.0069 lb/ton (see 1981 overburden stripping phase, Calculation 1)

Operational Parameters:

To East Gulch fill	243,000 yd^3/yr
To Containment Dike fill	1,714,000 yd^3/yr

Uncontrolled Emissions:

$$E = (0.0069\ lb/ton)(1{,}957{,}000\ yd^3/yr)(1.825\ ton/yd^3)$$
$$= 24{,}644\ lb/yr = 12.32\ ton/yr$$

Short-term Emissions:

$$\frac{(24{,}644\ lb/yr)(454\ g/lb)}{(261\ day/yr)(24\ hr/day)(3{,}600\ sec/hr)} = 0.50\ g/sec$$

(PSD and NAAQS source)

2. OVERBURDEN HAUL

EF = 1.65 lb/VMT (see 1981 overburden stripping phase, Calculation 2)

Operational Parameters:

To East Gulch fill	243,000 yd^3/yr	(400 ft one way)
To Containment Dike fill	1,714,000 yd^3/yr	(7,800 ft one way)

$$VMT_{EGF} = \frac{(243{,}000\ yd^3/yr)(2 \times 400\ ft)}{(47\ yd^3/trip)(5{,}280\ ft/mile)} = 783\ VMT/yr$$

$$VMT_{CDF} = \frac{(1{,}714{,}000\ yd^3/yr)(2 \times 7{,}800\ ft)}{(47\ yd^3/trip)(5{,}280\ ft/mile)} = 107{,}747\ VMT/yr$$

Uncontrolled Emissions:

$$E_{EGF} = (1.65\ lb/VMT)(783\ VMT/yr) = 1{,}292\ lb/yr$$
$$= 0.65\ ton/yr$$

$$E_{CDF} = (1.65\ lb/VMT)(107{,}747\ VMT/yr) = 177{,}783\ lb/yr$$
$$= 88.89\ ton/yr$$

Controlled Emissions (PSD Source)

Control factor = 0.15 (85% control for lignon sulfonate or equivalent)

$$E_{EGF} = (0.65\ ton/yr)(0.15) = 0.10\ ton/yr$$

Short-term emissions:

$$\frac{(0.10\ \text{ton/yr})(2{,}000\ \text{lb/ton})(454\ \text{g/lb})}{(261\ \text{day/yr})(24\ \text{hr/day})(3{,}600\ \text{sec/hr})} = 0.00\ \text{g/sec}$$

Controlled Emissions (NAAQS Sources)

Control factor = 0.15

$E_{EGF + CDF}$ = (89.54 ton/yr)(0.15) = 13.43 ton/yr

Short-term emissions:

$$\frac{(13.43\ \text{ton/yr})(2{,}000\ \text{lb/ton})(454\ \text{g/lb})}{(261\ \text{day/yr})(24\ \text{hr/day})(3{,}600\ \text{sec/hr})} = 0.54\ \text{g/sec}$$

3. OVERBURDEN DUMPING

EF = 0.02 lb/ton (see 1981 Overburden Stripping Phase, Calculation 3)

Operational Parameters:

EGF: 243,000 yd^3/yr
CDF: 1,714,000 yd^3/yr

Uncontrolled Emissions:

E_{EGF} = (0.02 lb/ton)(243,000 yd^3/yr)(1.825 ton/yd^3)
= 8,870 lb/yr
= 4.44 ton/yr (PSD Source)

E_{CDF} = (0.02 lb/ton)(1,714,000 yd^3/yr)(1.825 ton/yd^3)
= 62,561 lb/yr
= 31.28 ton/yr (Not a PSD Source)

Short-term emissions:

$$\frac{(8{,}870\ \text{lb/yr})(454\ \text{g/lb})}{(261\ \text{day/yr})(24\ \text{hr/day})(3{,}600\ \text{sec/hr})} = 0.18\ \text{g/sec (PSD Source)}$$

$$\frac{(71{,}431\ \text{lb/yr})(454\ \text{g/lb})}{(261\ \text{day/yr})(24\ \text{hr/day})(3{,}600\ \text{sec/hr})} = 1.44\ \text{g/sec (NAAQS Source)}$$

4. ORE REMOVAL

EF = 0.000069 lb/ton (see 1983 operations, Calculation 7)

Operational Parameter:

1,800,000 ton/yr

Uncontrolled Emissions:

E = (0.000069 lb/ton)(1,800,000 ton/yr) = 124 lb/yr
= 0.06 ton/yr

Short-term emissions:

$$\frac{(124\ \text{lb/yr})(454\ \text{g/lb})}{(261\ \text{day/yr})(24\ \text{hr/day})(3{,}600\ \text{sec/hr})} = 0.00\ \text{g/sec}$$

(PSD and NAAQS Source)

5. ORE HAULING

EF = 1.65 lb/VMT (see 1981 Overburden Stripping Phase, Calculation 2)

Operational Parameter:

61,998 VMT/yr (see 1983 Operations, Calculation 8)

Uncontrolled Emissions:

E = (1.65 lb/VMT)(61,998 VMT/yr) = 102,297 lb/yr
= 51.15 ton/yr

Controlled Emissions:

Control Factor = 0.15 (85% control for lignon sulfonate or equivalent)

E = (51.15 ton/yr)(0.15) = 7.67 ton/yr

Short-term emissions:

$$\frac{(7.67\ \text{ton/yr})(2{,}000\ \text{lb/ton})(454\ \text{g/lb})}{(261\ \text{day/yr})(24\ \text{hr/day})(3{,}600\ \text{sec/hr})} = 0.31\ \text{g/sec}$$

(PSD and NAAQS Source)

6. ORE DUMPING

EF = 0.000069 lb/ton (see 1983 operations, Calculation 9)

Operational Parameter:

1,800,000 ton/yr

Uncontrolled Emissions:

E = (0.000069 lb/ton)(1,800,000 ton/yr) = 124 lb/yr
= 0.06 ton/yr

Short-term emissions:

$$\frac{124 \text{ lb/yr})(454 \text{ g/lb})}{(261 \text{ day/yr})(24 \text{ hr/day})(3{,}600 \text{ sec/hr})} = 0.00 \text{ g/sec}$$

(PSD and NAAQS Source)

7. WATER TRUCK TRAFFIC

See 1983 operations, Calculation 10

Controlled Emissions:

E = 0.86 ton/yr

Short-term emissions:

0.03 g/sec

(PSD and NAAQS Source)

8. ACCESS ROAD TRAFFIC

See 1982 operations, Calculation 7

Controlled Emissions:

E = 3.71 ton/yr

Short-term Emissions:

0.15 g/sec

(PSD and NAAQS Source)

9. TOPSOIL EROSION

See 1982 operations, Calculation 8

Controlled Emissions:

E = 1.07 ton/yr

Short-term emissions:

0.03 g/sec

(PSD and NAAQS Source)

10. OVERBURDEN EROSION

EF = 0.0576 ton/acre-yr (see 1981 Overburden Stripping Phase, Calculation 8)

Operational Parameter

In 1984 the spent shale will cover some of the inside portion of the previously constructed Phase I overburden dikes. Also, in 1984 there is additional overburden used to construct additional Phase II dikes (1,714,000 yd^3) and to fill the East Gulch (243,000 yd^3). Therefore, the total exposed overburden area previously used in the 1982 and 1983 calculations (166 acres) will be decreased because of the addition of spent shale but increased because of additional overburden dumping in 1984. Assume that the decreased overburden surface area due to the addition of spent shale is equal to the increased overburden surface area due to the additional overburden dumped in 1984. Therefore, assume the 166 acres calculated for 1982 operations is applicable to 1984 operations.

Controlled Emissions:

E = 2.39 ton/yr

Short-term emissions:

0.07 g/sec

(PSD and NAAQS Source)

11. ORE STOCKPILE WIND EROSION

EF = 0.00758 ton/acre-yr (see 1983 Operations, Calculation 14)

Operational Parameter:

Assume the surface area of the stockpiles in 1984 is increased over the stockpile area in 1983 by a factor equivalent to the ore removed in 1984 (1,800,000 tons) divided by the ore removed in 1983 (1,200,000 tons).

(28.9 acres) (1.8/1.2) = 43.4 acres

Uncontrolled Emissions:

E = (0.00758 ton/acre-yr)(43.4 acres) = 0.33 ton/yr

Short-term emissions:

$$\frac{(0.33\ \text{ton/yr})(2{,}000\ \text{lb/ton})(454\ \text{g/lb})}{(365\ \text{day/yr})(24\ \text{hr/day})(3{,}600\ \text{sec/hr})} = 0.01\ \text{g/sec}$$

(PSD and NAAQS Source)

12. TOPSOIL REMOVAL

EF = 0.38 lb/yd^3

Operational Parameters:

From East Gulch fill	90,900 yd^3/yr
From Phase II dike area	162,200 yd^3/yr

Uncontrolled Emissions:

$$E_{EGF} = (0.38\ lb/yd^3)(90{,}900\ yd^3/yr) = 34{,}542\ lb/yr = 17.27\ ton/yr$$

$$E_{P2DA} = (0.38\ lb/yd^3)(162{,}200\ yd^3/yr) = 61{,}636\ lb/yr = 30.82\ ton/yr$$

Controlled Emissions:

Control factor = 0.5 (50% control for watering)

$$E_{EGF} = (17.27\ ton/yr)(0.5) = 8.64\ ton/yr$$

$$E_{P2DA} = (30.82\ ton/yr)(0.5) = 15.41\ ton/yr$$

Short-term emissions:

$$\frac{(8.64\ ton/yr)(2{,}000\ lb/ton)(454\ g/lb)}{(261\ day/yr)(24\ hr/day)(3{,}600\ sec/hr)} = 0.35\ g/sec$$

$$\frac{(15.41\ ton/yr)(2{,}000\ lb/ton)(454\ g/lb)}{(261\ day/yr)(24\ hr/day)(3{,}600\ sec/hr)} = 0.62\ g/sec$$

PSD emissions (EGF):	0.35 g/sec	8.64 ton/yr
NAAQS emissions (EGF + P2DA):	0.97 g/sec	24.05 ton/yr

13. TOPSOIL HAULING

EF = 0.703 lb/VMT (see 1981 Construction Phase, Calculation 2)

Operational Parameters:

From East Gulch fill	1,700 ft
From Phase II dike area	1,700 ft

$$VMT_{EGF} = \frac{(90{,}900\ yd^3/yr)(2 \times 1{,}700\ ft)}{(28\ yd^3/trip)(5{,}280\ ft/mi)} = 2{,}091\ VMT/yr$$

$$VMT_{P2DA} = \frac{(162{,}200\ yd^3/yr)(2 \times 1{,}700\ ft)}{(28\ yd^3/trip)(5{,}280\ ft/mi)} = 3{,}730\ VMT/yr$$

Uncontrolled Emissions:

$$E_{EGF} = (0.703\ lb/VMT)(2{,}091\ VMT/yr) = 1{,}470\ lb/yr = 0.74\ ton/yr$$

E_{P2DA} = (0.703 lb/VMT)(3,730 VMT/yr) = 2,622 lb/yr
= 1.31 ton/yr

Controlled Emissions:

Control factor = 0.15 (85% control for lignon sulfonate or equivalent)

E_{EGF} = (0.74 ton/yr)(0.15) = 0.11 ton/yr

E_{P2DA} = (1.31 ton/yr)(0.15) = 0.20 ton/yr

Short-term emissions:

$$\frac{(0.11\ \text{ton/yr})(2{,}000\ \text{lb/ton})(454\ \text{g/lb})}{(261\ \text{day/yr})(24\ \text{hr/day})(3{,}600\ \text{sec/hr})} = 0.00\ \text{g/sec}$$

$$\frac{(0.20\ \text{ton/yr})(2{,}000\ \text{lb/ton})(454\ \text{g/lb})}{(261\ \text{day/yr})(24\ \text{hr/day})(3{,}600\ \text{sec/hr})} = 0.01\ \text{g/sec}$$

PSD emissions (EGF):	0.00 g/sec	0.11 ton/yr
NAAQS emissions (EGF + P2DA):	0.01 g/sec	0.31 ton/yr

14. TOPSOIL DUMPING

EF = 0.03 lb/yd^3

Operational Parameters:

East Gulch fill	90,900 yd^3/yr
Phase II dike area	162,200 yd^3/yr

Uncontrolled Emissions:

E_{EGF} = (0.03 lb/yd^3)(90,900 yd^3/yr) = 2,727 lb/yr
= 1.36 ton/yr

E_{P2DA} = (0.03 lb/yd^3)(162,200 yd^3/yr) = 4,866 lb/yr
= 2.43 ton/yr

Controlled Emissions:

Control factor = 0.5 (50% control for watering)

E_{EGF} = (1.36 ton/yr)(0.5) = 0.68 ton/yr

E_{P2DA} = (2.43 ton/yr)(0.5) = 1.22 ton/yr

Short-term emissions

$$\frac{(0.68\ \text{ton/yr})(2{,}000\ \text{lb/ton})(454\ \text{g/lb})}{(261\ \text{day/yr})(24\ \text{hr/day})(3{,}600\ \text{sec/hr})} = 0.03\ \text{g/sec}$$

$$\frac{(1.22\ \text{ton/yr})(2{,}000\ \text{lb/ton})(454\ \text{g/lb})}{(261\ \text{day/yr})(24\ \text{hr/day})(3{,}600\ \text{sec/hr})} = 0.05\ \text{g/sec}$$

PSD emissions (EGF): 0.03 g/sec 0.68 ton/yr

NAAQS emissions (P2DA + EGF): 0.08 g/sec 1.70 ton/yr

15. RUN OF MINE ORE LOAD OUT FROM ORE STOCKPILE

EF = 0.0011 lb/ton (see 1983 Operations, Calculation 18)

Operational Parameters:

4,400 ton/day

50% annual online rate

Uncontrolled Emissions:

E = 0.44 ton/yr

Short-term emission:

0.03 g/sec

(PSD and NAAQS Source)

16. RUN OF MINE LOAD IN TO PRIMARY CRUSHER HOPPER

EF = 0.0022 lb/ton (see 1983 Operations, Calculation 19)

Operational Parameters:

4,400 ton/day

50% annual online rate

Uncontrolled Emissions:

E = 0.88 ton/yr

Short-term emissions:

0.05 g/sec

(PSD and NAAQS Source)

17. ORE AND OVERBURDEN DRILLING

See 1982, Calculation 11

Controlled Emissions:

E = 0.61 ton/yr

Short-term emissions:

0.02 g/sec

(PSD and NAAQS Source)

18. BLASTING

See 1982, Calculation 12

Uncontrolled Emissions:

E = 5.07 ton/yr

Controlled Emissions:

Control factor = 0.5 (50% control assumed because blasts are in aquifer)

E = (5.07 ton/yr) (0.5) = 2.54 ton/yr

Short-term emissions:

$$\frac{(2.54 \text{ ton/yr})\ (2{,}000 \text{ lb/ton})\ (454 \text{ g/lb})}{(261 \text{ day/yr})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 0.10 \text{ g/sec}$$

(PSD and NAAQS Source)

19. DISTURBED AREAS EROSION

See 1982, Calculation 13

Controlled Emissions:

E = 17.34 ton/yr

Short-term emissions:

0.50 g/sec

(PSD and NAAQS Source)

20. PRIMARY CRUSHING/SCREENING

EF = 0.02 lb/ton crushing (PEDCo 1978)

EF = 0.10 lb/ton screening (PEDCo 1978)

Total EF = 0.12 lb/ton

Uncontrolled Emissions:

E = (0.12 lb/ton) (803,000 ton/yr) = 96,360 lb/yr
= 48.18 ton/yr

Short-term emissions:

$$\frac{(0.12\ \text{lb/ton})\ (4{,}400\ \text{ton/day})\ (454\ \text{g/lb})}{(24\ \text{hrs/day})\ (3{,}600\ \text{sec/hr})} = 2.77\ \text{g/sec}$$

Controlled Emissions:

Control technique - baghouse

Percent Control - 99% (EPA Region VIII 1979)

(48.18 ton/yr) (0.01) = 0.48 ton/yr

(2.77 g/sec) (0.01) = 0.03 g/sec

(PSD and NAAQS Source)

21. SECONDARY CRUSHING/SCREENING

EF = 0.06 lb/ton crushing (PEDCo 1978)

EF = 0.10 lb/ton screening (PEDCo 1978)

Total EF = 0.16 lb/ton

Uncontrolled Emissions

E = (0.16 lb/ton) (803,000 ton/yr) = 128,480 lb/yr
= 64.24 ton/yr

Short-term emissions:

$$\frac{(0.16\ \text{lb/ton})\ (4{,}400\ \text{ton/day})\ (454\ \text{g/lb})}{(24\ \text{hrs/day})\ (3{,}600\ \text{sec/hr})} = 3.70\ \text{g/sec}$$

Controlled Emissions:

Control technique - baghouse

Percent control - 99% (EPA Region VIII 1979)

(64.24 ton/yr) (0.01) = 0.64 ton/yr

(3.7 g/sec) (0.01) = 0.04 g/sec

(PSD and NAAQS Source)

22. CRUSHED ORE CONVEYING TO BUILDING CONTAINING CRUSHED ORE STOCKPILE

EF = 0.2 lb/ton (PEDCo 1978)

Uncontrolled Emissions:

E = (0.2 lb/ton) (803,000 ton/yr) = 160,600 lb/yr
= 80.3 ton/yr

Short-term emissions:

$$\frac{(0.2\ \text{lb/ton})\ (4{,}400\ \text{ton/day})\ (454\ \text{g/lb})}{(24\ \text{hrs/day})\ (3{,}600\ \text{sec/hr})} = 4.62\ \text{g/sec}$$

Controlled Emissions:

Control technique - baghouse

percent control - 99% (EPA Region VIII 1979)

(80.3 ton/yr) (0.01) = 0.8 ton/yr

(4.62 g/sec) (0.01) = 0.05 g/sec

(PSD and NAAQS Source)

23. CRUSHED ORE LOAD OUT FROM BUILDING CONTAINING CRUSHED ORE STOCKPILE

EF = 0.05 lb/ton (PEDCo 1978)

Uncontrolled Emissions:

See 1983 Operations, Calculation 23

20.08 ton/yr
1.16 g/sec

Controlled Emissions:

Control Technique - baghouse

Percent control - 99% (EPA Region VIII 1979)

(20.08 ton/yr (0.01) = 0.20 ton/yr

(1.16 g/sec) (0.01) = 0.01 g/sec

(PSD and NAAQS Source)

24. CRUSHED ORE CONVEYING TO FEED HOPPER "UPSTREAM" OF BELTAVATOR

EF = 0.2 lb/ton (PEDCo 1978)

99% control with baghouse (EPA Region VIII 1979)

As per Calculation 22

0.80 ton/yr
0.05 g/sec

(PSD and NAAQS Source)

25. CRUSHED ORE TRANSFER TO LURGI FEED HOPPER VIA BELTAVATOR

EF = 0.2 lb/ton (PEDCo 1978)

99% control with baghouse (EPA Region VIII 1979)

As per Calculation 22

0.80 ton/yr
0.05 g/sec

(PSD and NAAQS Source)

26. PROCESSED SHALE TRANSFER VIA ROTARY FEEDER AND CONVEYER TO COLLECTING HOPPER

EF = 0.2 lb/ton (PEDCo 1978)

99% control with baghouse (EPA Region VIII 1979)

As per Calculation 22

0.80 ton/yr
0.05 g/sec

(PSD and NAAQS Source)

27. PROCESSED SHALE TRANSFER FROM THE COLLECTING HOPPER TO PROCESSED SHALE DISPOSAL AREA

EF = 0.2 lb/ton (PEDCo 1978)

99% control with baghouse (EPA Region VIII 1979)

As per Calculation 22
0.80 ton/yr
0.05 ton/yr

(PSD and NAAQS Source)

28. PROCESSED SHALE DISPOSAL VIA STACKER IN PROCESSED SHALE DISPOSAL AREA

EF = 0.2 lb/ton (PEDCo 1978)

90% control assumed because processed shale is moisturized

As per Calculation 22 but with 90% control

8.03 ton/yr
0.46 g/sec

(PSD and NAAQS Source)

29. PROCESSED SHALE WIND EROSION

EF = 0.025 IKCLV (Woodruff and Siddoway 1976)

Although the processed shale is wet, it will dry within a few days (Golder 1980). Dry processed shale can have a large percentage of fine particulate and therefore a potentially large value for the soil erodibility parameter "I". However, RBOSC tests show that wet processed shale bonds to itself much like concrete with a very hard surface once it has set-up. Also, RBOSC wind tunnel tests (1980b) did not show any measurable erosion of processed shale piles (piles were compacted). However, the precision of the wind tunnel tests was not small enough to say, absolutely, there will be no erosion. In addition, it is possible that the actual processed shale piles will be uncompacted.

As a first approximation, assume the wind erosion of the processed shale piles to be equal (per unit area) to the overburden dikes.

EF = 0.0576 tons/acre year

Erosion Parameter:

30 acres (by plenimeter)

Uncontrolled Emissions:

(0.0576 ton/acre-yr) (30 acres) = 1.73 ton/yr

Short-term emissions:

$$\frac{(1.73 \text{ ton/yr})\ (2{,}000 \text{ lb/ton})\ (454 \text{ g/lb})}{(365 \text{ days/yr})\ (24 \text{ hr/day})\ (3{,}600 \text{ sec/hr})} = 0.05 \text{ g/sec}$$

(PSD and NAAQS Source)

Appendix C

APPENDIX C

HYDROCARBON EMISSION CALCULATIONS

The hydrocarbon emissions caused by tank storage and loading/unloading procedures at the Lurgi Demonstration Project were estimated using emission factors contained in the document titled "Compilation of Air Pollutant Emission Factors", United States Environmental Protection Agency, 1977. Sections 4.3, Storage of Petroleum Liquids, and 4.4, Transportation and Marketing of Petroleum Liquids, of the above document, provide empirical formulas for calculating projected emissions of total hydrocarbons as a result of normal storage and loading activities. The formula on pages 4.3-12, equation 3, and 4.4-5, equation 1, were used to predict the evaporative hydrocarbon emissions from the proposed storage facilities and loading operations, respectively.

Evaporative hydrocarbon emissions from a floating roof storage tank can be estimated from:

$$L_S = 9.21 \times 10^{-3} M \left[\frac{P}{11.4-P} \right]^{0.7} D^{1.5} V_w^{0.7} K_t K_s K_p K_c$$

where:
- L_S = Floating roof standing storage loss (lb/day)
- M = Molecular weight of vapor in storage tank (lb/lb mole)
- P = True vapor pressure at bulk liquid conditions (psia)
- D = Tank diameter (ft)
- V_w = Average wind velocity (mi/hr)
- K_t = Tank type factor (dimensionless)
- K_s = Seal factor (dimensionless)
- K_p = Paint factor (dimensionless)
- K_c = Crude oil factor (dimensionless)

In this analysis, 11.4 was assumed to be the average atmospheric pressure at Tract C-a.

The parameters used for each proposed storage tank facility are shown below. The parameters were selected based on data provided by the Lummus Company on loading and storage facilities for the Lurgi Demonstration Project. The dimensionless parameters were estimated using the guidance in AP-42.

TABLE C-1

DATA USED TO CALCULATE EVAPORATIVE HYDROCARBON EMISSIONS

Parameter	Emission Source						
	Product Storage Tank	Product Storage Tank	Diesel Fuel Storage	Diesel Fuel Day Tank	Diesel Fuel Day Tank	Gasoline Storage	Waste Oil Storage
M (lb/lb mole)	190	190	170	170	170	66	150
P (psia)	1.0	1.0	1.0	1.0	1.0	3.4	1.0
D (ft)	82	82	15	6.5	6.5	8	12
V_w (mph)	7.7	7.7	7.7	7.7	7.7	7.7	7.7
K_t	0.045	0.045	0.045	0.045	0.045	0.045	0.045
K_s	1.0	1.0	1.0	1.0	1.0	1.0	1.0
K_p	0.9	0.9	0.9	0.9	0.0	0.9	0.9
K_c	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Emissions from loading hydrocarbon liquid can be estimated using the following expression:

$$L_L = 12.46 \frac{SPM}{T}$$

Where: L_L = Loading loss, lb/10^3 gallon of liquid loaded.
M = Molecular weight of vapors, lb/lb-mole
P = True vapor pressure of liquid loading, psia
T = Bulk temperature of liquid loaded, °R.
S = A saturation factor

Loading loss calculations were performed for the product oil loading station and the diesel unloading station.

The molecular weights and vapor pressures used for the loading emission points have been presented. The saturation factor applied was 0.60, which is the value recommended in EPA publication AP-42 for submerged loading with normal dedicated service. The bulk temperature of the liquid loaded was taken to be 130°F (590°R) for the product oil loading and 50°F (510°R) for the diesel unloading.

An annual average wind speed of 7.7 miles per hour was used in the evaporative emissions calculations. An average barometric pressure of 11.4 psia was assumed for the storage tank calculations.

The control efficiency for the loading operations at the product oil loading station, is projected to be approximately 85 percent (Personal communication with B. Fogman of The Lummus Company). Thus, uncontrolled emissions were multiplied by 0.15 to give the emissions presented for this source.

The combined hydrocarbon emissions calculated with this method are 21.7 tons per year of hydrocarbon. Because of uncertainties in precise vapor pressures, the control efficiency, and wind speed and atmospheric pressure variability, 21.7 tons per year is a rough estimate of hydrocarbon emissions. The emissions calculated with equations in the AP-42 document are reported to be within plus or minus 25 to 30 percent of actual emissions.

Appendix D

APPENDIX D

VISIBILITY SCREENING TEST

VISIBILITY SCREENING TEST

EPA's draft guidelines for estimating visibility impairment specify five critical parameters used to estimate the potential for visibility impairment in a Class I area. The values of the derived parameters, C_1, C_2, and C_3, determine the potential for visibility impairment.

Parameter 1 - Minimum Distance From the Project to the Class I Area

The following table delineates the receptors in the Flat Tops Wilderness Area (as shown in Figure 4-5 of the text) and their respective distances from the Lurgi Demonstration Project.

Receptor Number	Distance from the Lurgi, km
121	81.86
122	84.16
123	86.30
124	81.20
125	86.90

Therefore, the minimum distance of the Lurgi Demonstration Project to the Flat Tops Wilderness Area is 81.2 km.

Parameter 2 - Geographic Location of the Project and the Class I Area

Both the Lurgi Demonstration Project and the Flat Tops Wilderness Area are located in western Colorado where the background visual range, as shown on the map in EPA's draft guidelines, is 170 km.

Parameters 3, 4 and 5 - Particulate, SO_2, and NO_x Emission Rates, Respectively

The total emission rates from the Lurgi and MIS operations are:

Particulate	6.7 g/sec = 0.58 metric tons/day
SO_2	14.1 g/sec = 1.26 metric tons/day
NO_x	49.3 g/sec = 4.25 metric tons/day

Step 1:

$$p = \frac{2.0 \times 10^8}{\sigma_z X} = \frac{2.0 \times 10^3}{(90m)(81.2\ km)} = 27{,}367$$

where σ_z = standard deviation of the Gaussian plume distribution in the vertical, m

X = minimum distance, km

Step 2:

$$\tau_{particulate} = (10 \times 10^{-7})(p)(Q\ particulate)$$
$$= (10 \times 10^{-7})(27{,}367)(0.58)$$
$$= 0.01587$$

$$\tau_{NO_2} = (1.7 \times 10^{-7})(p)(Q_{NO_2})$$
$$= (1.7 \times 10^{-7})(27{,}367)(4.25)$$
$$= 0.01977$$

where Q = the emission rate of the pollutant, metric tons/day

Step 3:

$$r_{vo} = 170\ km$$

where r_{vo} = background visual range, km

Step 4:

$$\tau^1 = (1.06 \times 10^{-5})(r_{vo})Q \text{ part} + 1.31\, Q_{SO_2})$$
$$= (1.06 \times 10^{-5})(170 \text{ km})\ [0.58 + (1.31)(1.26)]$$
$$= 0.00402$$

Step 5:

$$C_1 = -\left[\frac{\tau_{NO_2}}{\tau_{part} + \tau_{NO_2}}\right]\left[1 - \exp\left(-\tau_{part} - \tau_{NO_2}\right)\right]\exp\left[\frac{-(0.78)(X)}{\sigma_z}\right]$$

$$= -\left[\frac{0.01977}{0.01587 + 0.01977}\right]\left[1 - \exp\left(-0.01587 - 0.01977\right)\right]\exp\left[\frac{-(0.78)(81.2)}{170}\right]$$

$$= -0.01338$$

$$C_2 = \left[1 - \frac{1}{C_1 + 1}\exp\left(-\tau_{part} - \tau_{NO_2}\right)\right]\exp\left[\frac{-1.56\ X}{r_{vo}}\right]$$

$$= \left[1 - \frac{1}{1 - 0.01338}\exp\left(-0.01587 - 0.01977\right)\right]\exp\left[\frac{(-1.56)(81.2)}{170}\right]$$

$$= 0.01041$$

$$C_3 = 0.368\ [1 - \exp\ (-\tau^1)]$$

$$= 0.368\ [1 - \exp\ (-0.00402)]$$

$$= 0.0015$$

The absolute values of C_1, C_2, and C_3 are all less than 0.1. Therefore, according to EPA's guideline, the Lurgi Demonstration Project can be assumed to have little or no impact on visibility in the Flat Tops Wilderness Area.

Appendix E

APPENDIX E

METHODOLOGY FOR EMPLOYMENT AND POPULATION PROJECTIONS

METHODOLOGY FOR EMPLOYMENT AND POPULATION PROJECTIONS

Determination of Project Employment and Import Employment (Table E-1)

Manpower loading (construction and operations workforce) was derived from peak employment figures and project phasing information provided by the Rio Blanco Oil Shale Company for the period from May 1981 through 1986. Where specific employment figures were not provided, employment levels for that phase were extrapolated from peak figures. Import (non-local) employemnt was assumed to be 50 percent of both construction and operation employment based on data from the existing RBOSC workforce on site.

Determination of Service Employment (Table E-1)

Service (or non-base) employment was projected using an employment multiplier, which expresses the relationship between project (base) employment and secondary (non-base) employment generated in other sectors of the local economy. The multipliers used here were derived from actual employment surveys associated with similar projects in northwestern Colorado and elsewhere in the Rocky Mountain states. Different service employment ratios were used for the "with" vs "without constructions camp" scenarios for projecting construction-related service employment because previous experience has shown that construction workers living onsite (often commuting home on weekends) typically generate a lower level of local spending and employment than construction workers living in local communities. The employment multiplier used for the "with construction camp" scenario was 0.3 for the "without camp" scenario, 0.6. A 1.5 service employment multiplier was used for projecting operations-related service employment under both scenarios.

For example, for 1982, the project construction employment was 274, of which half or 137, was non-local. Without the construction camp, 82 (137 x 0.6) service jobs would be generated, for a total construction-related imported employment of 219 (137 + 82). With the camp, the total would be 178 (137 x 0.3 = 41, 41 + 137 = 180). Thus, total imported employment would be 399 without the construction camp (219 + 180), or 358 (178 + 180) with the camp.

TABLE E-1

METHODOLOGY FOR TRACT C-a EMPLOYMENT AND POPULATION PROJECTIONS

	May Dec 1981	1982	1983	1984	1985	1986
Assumed Manpower Loading						
Construction	2001	274	1501	--	--	--
Operation	--	1431	248	248	248	2481
TOTAL	200	417	398	248	248	248
Base (Project) Imported Employment						
Construction (x.50)	100	137	75			
Operation (x.50)		72	124	124	124	124
TOTAL	100	209	199	124	124	124
Non-Base (Service) Imported Employment (Without Construction Camp)						
Construction (x.60)	60	82	45	--	--	--
Operation (x1.5)		108	186	186	186	186
Total	60	190	231	186	186	186
TOTAL IMPORTED EMPLOYMENT (Without Construction Camp)	160	399	430	310	310	310
Non-Base (Service) Imported Employment (With Construction Camp)						
Construction (x.30)	30	41	23	--	--	--
Operation (x1.5)	--	108	186	186	186	186
TOTAL	30	149	209	186	186	186
TOTAL IMPORTED EMPLOYMENT (With Construction Camp)	130	358	408	310	310	310

1Extrapolated from RBOSC phasing and employment data.

Population Projection Scenarios (Table E-2 and E-3)

The same methodology and assumptions were used to project population impacts under both scenarios, although the total population levels differ because of the variation in construction-related service employment multipliers described above. In addition, it was assumed a much lower proportion of construction workers (10 percent versus 60 percent) would have families present if the construction workers were housed in an on-site camp.

Household size and family characteristics were derived from data for northwestern Colorado and workforces associated with similar projects in the region. It was assumed that 85 percent of oeprations workers would be married with families present, compared to only 60 percent of construction workers (without the construction camp, 10 percnet with camp) and service employees. Family size was assumed to be 2.71 for construction and oeprations employees; 3.05 for service workers. The total popualtion associated with each category of worker was then calculated by multiplying the workforce by the percent married and family size factors and adding the single employees. For example, in 1982 of the 137 imported construction employees, 60 percent or 82 would be married with familes present, generating a total of 178 people (82.2 x 2.71 222.8; 222.8 + 54.8 277.6). Operations and service workers would generate 177 and 422 people, respectively, for a total popualtion influx of 877. Comparable figures for the "with camp" scenario would be a total construction-related population increase of 160 (137 x 10 = 13.7, 13.7 x 2.71 = 37.1, 37.1 + 123.3 = 160.4); operations and service-related population icnreases of 177 and 331, respectively, for a total population influx of 668.

Distribution of Population Influx Among Local Communities (Table E-4)

The total population influx under each scenario was distributed among local communities based on residential distribution patterns of the current workforce. Under the "without camp" scenario 83 percent of the population was allocated to Rifle, 13 percent of Meeker, and 4 percent to Rangely. Under the "with camp" scenario, construction and service-related single employemnt was allocated to the camp, e.g., 164 workers in 1982, and the remainder of the population influx was distributed among local communities using the same ratios. For example, in 1982, 164 people would live in the camp, and the

TABLE E-2

POPULATION PROJECTION SCENARIOS

WITHOUT CONSTRUCTION CAMP

	May Dec 1981	1982	1983	1984	1985	1986
Construction-Related Population Increase (60% with families; 2.71 family size)						
Imported Construction Employment	100	137	75	--	--	--
x.60	60	82.2	45	--	--	--
x2.71	162.6	222.8	122.0	--	--	--
+singles	40.0	54.8	30.0	--	--	--
Total	202.6	277.6	152.0	--	--	--
Ratio	2.03	2.03	2.03	--	--	--
Operation-Related Population Increase (85% with families; 2.71 family size)						
Imported Operation Employment	--	72	124	124	124	124
x.85	--	61.2	105.4	105.4	105.4	105.4
x2.71	--	165.9	285.6	285.6	285.6	285.6
+singles			10.8	18.6	18.6	18.6
Total	--	176.7	304.2	304.2	304.2	304.2
Ratio			2.45	2.45	2.45	2.45
Service-Related Population Increase (60% with families; 3.04 family size)						
Imported Service Employment	60	190	231	186	186	186
x.60	36	114	138.6	111.6	111.6	111.6
x3.04	109.4	346.6	421.3	339.3	339.3	339.3
+singles	24.0	76.0	92.4	74.4	74.4	74.4
Total	133.4	422.6	513.7	413.7	413.7	413.7
Ratio	2.22	2.22	2.22	2.22	2.22	2.22

TABLE E-3

POPULATION PROJECTION SCENARIOS
WITHOUT CONSTRUCTION CAMP

	May Dec 1981	1982	1983	1984	1985	1986
Construction-Related Population Increase (10% with families; 2.71 family size)						
Imported Construction Employment	100	137	75	--	--	--
x.10	10	13.7	7.5	--	--	--
x2.71	27.1	37.1	20.3	--	--	--
+singles	90.0	123.3	67.5	--	--	--
Total	117.1	160.4	87.8	--	--	--
Ratio	1.17	1.17	1.17	--	--	--
Operation-Related Population Increase (85% with families; 2.71 family size)						
Imported Operation Employment	--	72	124	124	124	124
x.85	--	61.2	105.4	105.4	105.4	105.4
x2.71	--	165.9	285.6	285.6	285.6	285.6
+singles			10.8	18.6	18.6	18.6
Total	--	176.7	304.2	304.2	304.2	304.2
Ratio			2.45	2.45	2.45	2.45
Service-Related Population Increase (60% with families; 3.04 family size)						
Imported Service Employment	30	149	209	186	186	186
x.60	18	89.4	125.4	111.6	111.6	111.6
x3.04	54.7	271.8	381.2	339.3	339.3	339.3
+singles	120	59.6	83.6	74.4	74.4	74.4
Total	66.7	331.4	464.8	13.7	413.7	413.7
Ratio	2.22	2.22	2.22	2.22	2.22	2.22
Construction & Service-Related Single Employment with Camp	120	164.3	90.5	--	--	--

TABLE E-4

POPULATION PROJECTION SCENARIOS SUMMARY

	May Dec 1981	1982	1983	1984	1985	1986
Total Population Influx						
With Camp	184	669	857	718	718	
Without Camp	336	877	970	718	718	
Population Distribution, %						
With Camp						
Rifle	53	418	636	596	596	596
Meeker	8	66	100	93	93	93
Rangley	3	20	31	29	29	29
Const. Camp	120	164	91	--	--	--
Without Camp						
Rifle 83%	279	728	805	596	596	596
Meeker 13%	44	114	126	93	93	93
Rangely 4%	13	35	39	29	29	29

remaining 504 would be distributed to Rifle, 418 (504 x .83); Meeker, 66 (504 x .13); and Rangely, 20 (504 x .04). These allocations assume of year-round access road to Rangely will not be constructed which would change the distribution significantly. Existing distribution patterns were used rather than a gravity distribution model approach because of the greater validity of verified data.

FIGURE 3-1
OIL SHALE PROJECTS IN PICEANCE BASIN AREA

January 22, 1981

Mr. J. Blaine Miller
Rio Blanco Oil Shale Company
2851 South Parker Road
Aurora, Colorado 80014

Re: Review of Environmental Monitoring Program Scope of Work - Revision 6.0

Dear Mr. Miller:

The Oil Shale Office (OSO) staff has reviewed the Environmental Monitoring Program Scope of Work - Revision 6.0, submitted to this office on December 19, 1980. Copies of the Scope of Work (SOW) have also been provided to the Oil Shale Environmental Advisory Panel for their future consideration. We regard this SOW as a draft submittal. A final SOW should be submitted to this office, for approval, prior to construction of the Lurgi Demonstration Project. This letter transmits our review and comments which consist of the following items:

1) general comments on the SOW that will be included in this letter; and

2) copy of the draft SOW with OSO staff marginal notes and specific comments.

The general comments are as follows:

- This office should be identified as the Oil Shale Office (OSO) throughout the SOW. My title should also be identified as the Deputy Conservation Manager - Oil Shale (DCM-OS).

- All maps within the SOW should include the boundaries of the "off-tract property".

- The intended objectives of the monitoring program should be clearly identified with respect to MIS and Lurgi operations. Is RBOSC's objective to separate and identify MIS and Lurgi impact sources; or will all impacts be cumulative? The control/treatment concept should also be introduced in the general discussion of monitoring program development.

- The revised environmental assessment matrix prepared for the Lurgi Demonstration Project should be provided to this office.

- The OSO is concerned with the general form of the null hypothesis for each of the monitoring programs, which follows:

1. H_o: There is no significant difference in x measured during the baseline period and the development phase.

2. H_o: There is no significant difference in x measured at a number of sites (control, treatment).

where x is the quantitative variable of interest.

In general, a two- or three-way hierarchial ANOVA is defined as the method of testing these hypotheses. Examples of this are pages 17, 22, 31, 51, 55, 58, 67-68, and 79-80, of the Scope of Work. The problem is that year-to-year variation is not accounted for. The phase x location interaction term in the ANOVA will most probably be significant. If this is the case, the corresponding main effects cease to have much meaning.

We suggest the following variable transformation to mitigate the effect of the natural variation:

$$x' = \log (\text{control station/affected station})^*$$

for baseline and development phases with years nested within phase. The logarithm transformation would tend to make the statistical errors additive, "normalize" a skewed underlying population distribution, and stabilize variance. The ratio will tend to compensate for localized differences (e.g., slope, soil conditions, topography, etc.) and the year-to-year variation. The null hypothesis for x' (the transformed variable) would simply be:

H_o': There is no significant difference in x' measured during the baseline and the development phase.

If a significant difference is noted, then Duncan's multiple range test or other "individual effects" tests could be used to determine the anomalous year.

The use of this transformation would require a clear differentiation between control and treatment stations. It is suggested that comparisons between station location and isopleths be used in this differentiation. In addition, historic graphs of each of the sites should be maintained to check for trends.

* The difference (control station - affected station) could also be used depending on the data.

— The discussion of monitoring methodology for each program element should address the precision obtained with the sampling design and the number of samples given. In addition, the actual precision (e.g., detection of $\pm$ 10% of the mean 90% of the time for a measured parameter) should be

1. H_o: There is no significant difference in x measured during the baseline period and the development phase.

2. H_o: There is no significant difference in x measured at a number of sites (control) treatment.

where x is the quantitative variable of interest.

In general, a two- or three-way interactional ANOVA is defined as the method of testing these hypotheses. Examples of this are found in 17, 22, 31, 32, 36, 37-38, and 39-40. At the time of work, the problem in that year-to-year variation is not accounted for. The phase x location interaction term in the ANOVA will more probably be significant. If this is the case, the corresponding main effects seems to have much meaning.

We consider the following variable transformation in utilizing the effect of the medical service:

$$x' = \log(\text{observed effect/expected effect}).$$

For baseline and development phases with years nested within phase, the logarithm transformation could lead to make the substantial effects additive. "Normalize" a skewed quantity, stabilize distribution, and stabilize variance. The ratio will tend to compensate for interactions (e.g., alpha, beta conditions, topography, etc.) and the year-to-year variations. The only expectation for x' (the transformed variable) would simply be:

H_o: There is no significant difference in x' measured during the baseline and the development phase.

If a significant difference is noted, then Tukey's multiple-range test or other "multiple effects" tests could be used to determine the significant year.

The use of this transformation would require a clear differentiation between control and treatment sites. It is considered that control-sites because their location and topography is based on a site differentiation. To multiple, activity values of each of the sites should be compared to these two types.

The differences (observed - expected effect) could also be more dependent on the data.

The dissection of monitoring methodology for each measure should address the population sampling and sampling, design and the tables of sampling plans. In addition, the annual monitoring, measures of ± 10% of the mean, 90% of the time are a standard practice should be

reported. This would indicate how well the sampling design is meeting or not meeting the criterion established by preliminary sampling.

- The unprotected plot productivity values (page 54-55 of the SOW) should not be included in the ANOVA. Normally, there will be a significant difference in the caged versus uncaged plots with a relatively larger variability in the yields of the uncaged plots because 1) the yields are estimated, and 2) utilization (within a year) is not constant over the ungrazed plots. The use of only the yields from the caged plots will lead to a smaller error term and thus a more sensitive test even though the sample size will be reduced by half.

- The range productivity and utilization sampling design (page 53) should call for estimating weight of herbage remaining in all plots - protected and unprotected. A specified number of protected and unprotected plots must also be clipped. The plots to be clipped must be randomly selected. For example:

  > Each transect has five protected and five unprotected plots randomly located along the transect. The randomization is for protected or unprotected, not plot location. A predetermined number of the protected and unprotected plots are clipped after the weight has been estimated. The plots to be clipped are also randomly selected, i.e., one plot of each five protected/unprotected is clipped. The clipped weights are used to adjust for observer error in the estimating.

  In the monitoring plan, only caged plots are clipped. Thus no error or observer bias is determined for the unprotected plots.

  It is important that the observer doing the estimating not weigh clipped samples in the field, as he automatically adjusts his estimates, thus confounding the adjustment factor.

- The location of open-pit and Lurgi hydrologic monitoring sites; air quality monitoring sites 7, 8, and 9; and the terrestrial studies treatment site 7 should be identified as soon as possible. This is especially important if off-tract land use permits are required. Early implementation of this revised monitoring program is of significant importance.

- This office will require the submittal for approval, of a detailed process stream and emission monitoring program prior to operations under the Lurgi Demonstration Project. This program would be broader in scope than the program presented in Section 2.2.

- Implementation of the soil trace metal and conductivity studies will be based upon refined modeling of meteorological data to determine treatment sites, and development of statistically sound sampling programs (Klusman, Colorado School of Mines).

We would be glad to discuss any of these concerns or specific comments with you during the final SOW rewrite. A meeting with your environmental staff has been scheduled for January 30, 1981, to discuss some of these areas.

Sincerely,

Peter A. Rutledge
Deputy Conservation Manager
Oil Shale

N 238,000
N 233,000
236,204N
161,650E
235,996N
163,161E
235,228N
159,176E
234,880N
161,805E
234,664N
165,113E
234,478N
164,421E
233,852N
159,123E
233,497N
161,761E
233,331N
163,065E
233,163N
164,370E
232,438N
159,070E
232,046N
161,713E
231,945N
165,015E
232,242N
160,392E
231,844N
164,317E
230,820.24N
160,391.30E
TOPSOIL
STOCKPILE
x6980
RBOSC PRIVATE
PROPERTY BOUNDARY
PHASE II
P/S
SEDIMENT
POND
E-8001
PHASE I P/S
SLURRY
TOPSOIL
STOCKPILE
x6940
SETTLING POND
WATER LEVEL (W.L.)
ELEVATION 7105
OIL SHALE
STOCKPILE
x7200
LURGI
SITE
CONTAINMENT DIKE
SUBSOIL STOCKPILE
TRACT C-a PROPERTY BOUNDARY
x 7205
OIL SHALE
STOCKPILE
SETTLING
POND
W.L. EL.
7120
PIPING CORRIDOR
UPPER HAUL
ROAD AREA
FLARE
E-4002
LURGI
ACCESS
ROAD
PIT DEWATERING
TREATMENT LAGOONS
EXPLOSIVES
STORAGE &
ACCESS ROAD
TOPSOIL
STOCKPILE
EL. 6950
ADJACENT HAUL ROAD FILL
(686,000 BCY)
TOPSOIL
STORAGE
EL. 7075
x 6950
FACILITIES AREA
(222,000 BCY)
SETTLING POND
W.L. EL. 7020
W.L. EL.
6903
6891
SETTLING POND
W.L. EL. 6886

TRACT C-a PROPERTY BOUNDARY
SETTLING POND WATER LEVEL (W.L.) ELEVATION 7105
OIL SHALE STOCKPILE
x7200
x6940
TOPSOIL STOCKPILE
CONTAINMENT OIKE SUBSOIL STOCKPILE
LURGI SITE
x 7205
OIL SHALE STOCKPILE
SETTLING POND W.L. EL. 7120
FLARE
E-4002
PIPING CORRIDOR
UPPER HAUL ROAD AREA
LURGI ACCESS ROAD
PIT DEWATERING TREATMENT LAGOONS
EXPLOSIVES STORAGE & ACCESS ROAD
TOPSOIL STOCKPILE EL. 6950
AOJACENT HAUL ROAD FILL (686,000 BCY)
TOPSOIL STORAGE EL. 7075
x 6950
FACILITIES AREA (222,000 BCY)
W.L. EL. 6905
6891
SETTLING POND W.L. EL. 7020
SETTLING POND W.L. EL. 6886
BOTTOM OF INITIAL PIT
BOTTOM OF FINAL PIT
CREST OF INITIAL PIT
CREST OF FINAL PIT
(637,000 BCY)
LOWER HAUL ROAD AREA
SHOP/OFFICE ACCESS ROAD (149,000 BCY)
E-6006
PIT/EAST GULCH TOPSOIL STOCKPILE
x 7150
SETTLING POND W.L. EL. 6980
SETTLING POND W.L. EL. 6807
SETTLING POND W.L. EL. 6700
x 6775
TOPSOIL STOCKPILES
SETTLING POND W.L. EL. 6728
M.I.S./PIT CORRIDOR
PROPOSED 4.16 KV POWER LINE (Secondary Distribution)
PIPING CORRIDOR
EAST GULCH FILL PHASE II (2,400,000 BCY) x 7190
EXISTING 138KV POWER LINE
PROJECT SITE
ORE PILE
PRODUCTION SERVICE SHAFT
EXISTING ACCESS ROAD
POWDER MAGAZINE
PROPOSED 138KV POWER LINE RELOCATION – PHASE II
SCRUBBER PONDS
WATER TANK
PROPOSED PUBLIC ACCESS ROAD RELOCATION
N 228,000
N 223,000

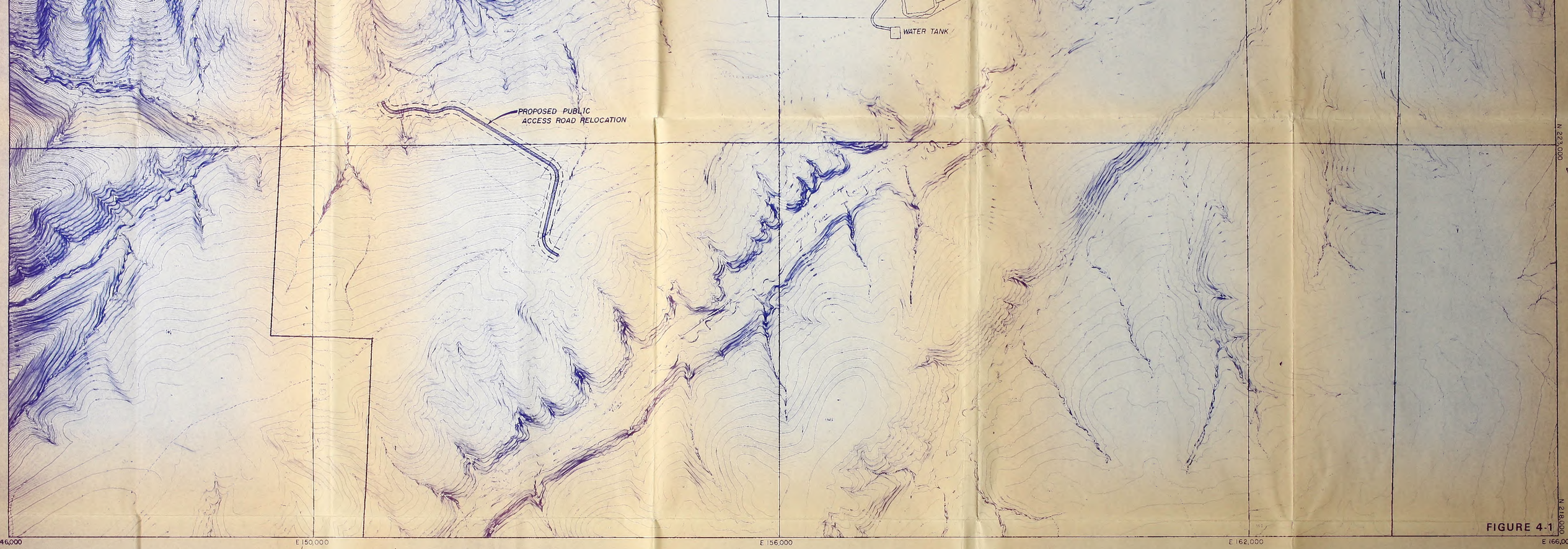
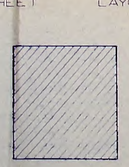
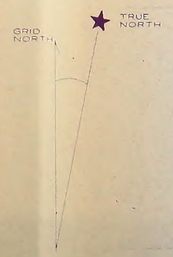
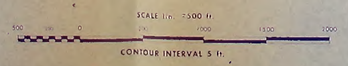


FIGURE 4-1

SHEET LAYOUT







LEGEND

- HORIZONTAL & VERTICAL CONTROL
- VERTICAL CONTROL
- HORIZONTAL CONTROL
- DRILL HOLE
- PROPERTY CORNER
- BRIDGE CENTER
- SECTION CORNER
- 1/4 CORNER
- SPOT ELEVATION
- INDEX CONTOUR
- INTERMEDIATE CONTOUR
- CONTOUR THRU HEAVY VEGETATION
- DEPRESSION
- PERENNIAL STREAM
- INTERMITTENT STREAM
- DITCH
- POND
- WASH
- CULTIVATION
- GRADED ROAD
- DIRT ROAD
- JEEP TRAIL
- TRAIL
- CULVERT
- FENCE
- FENCE (POSSIBLE)
- GATE
- CORRAL
- PIPE LINE
- BUILDING
- FOUNDATION
- EARTH DAM
- UTILITY POLE
- TREES
- SCATTERED TREES

Oxoy, 6014-148/11-80

REVISIONS

NO.	DESCRIPTION	DATE	BY

Rio Blanco Oil Shale Company
Rio Blanco County, Colorado

GENERAL PLOT PLAN

Drawn By:	Scale: 1" = 500'	Exhibit
Design By:	Date	
Approved By:	Drawing No.	

File

TOPOGRAPHIC MAPPING OF TRACT C-a FEDERAL OIL SHALE LEASE NO. C-20046 AND PORTIONS OF TOWNSHIPS 1&2 SOUTH, RANGES 98, 99&100 WEST RIO BLANCO COUNTY, COLORADO

NOTE: COMPILED BY PHOTOGRAMMETRIC METHODS FROM 1:12,000 PHOTOGRAPHY OBTAINED JUNE 1974 WITH AN RC 8 CAMERA OF 152.74mm FOCAL LENGTH. HORIZONTAL CONTROL SURVEYS REFERRED TO THE COLORADO STATE PLANE COORDINATE SYSTEM, NORTH ZONE MODIFIED TO A 7200 FT. DATUM. LAMBERT CONFORMAL CONIC PROJECTION. VERTICAL CONTROL SURVEYS RELATED TO MEAN SEA LEVEL.

SHEET ___ OF ___